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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *FORMATION OF ANODIC OXIDE COATINGS*

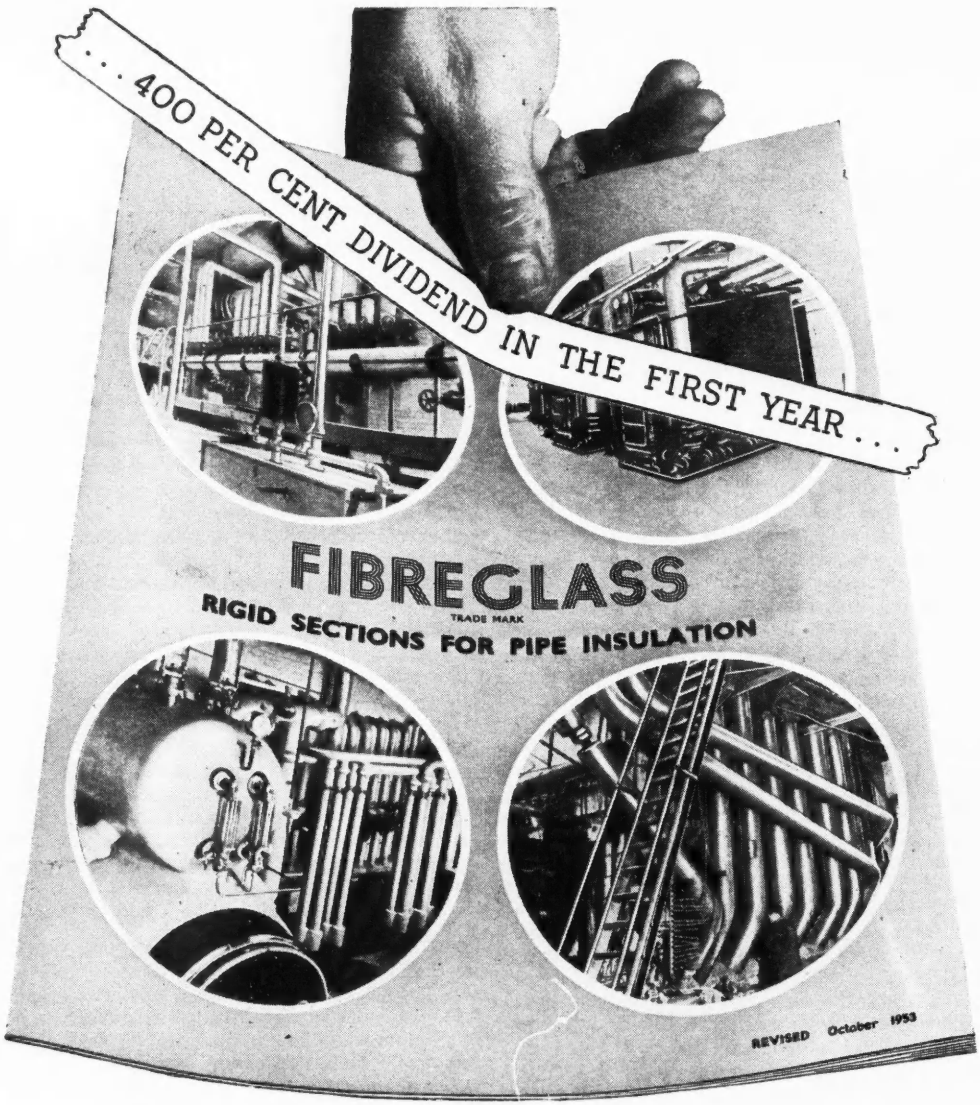
A recent paper gives important information concerning the effect of electrolyte and forming conditions on the production of the porous type of anodic oxide coatings on aluminium. By using the method of barrier-layer thickness measurement it has been found possible to study the factors affecting the barrier-layer thickness. These factors are the type of electrolyte, concentration of the electrolyte, bath temperature, voltage, current density, and time. The investigators found that the barrier-layer thickness remains constant with time, once the balance between formation and solution of oxide has been established. Investigation of an electrolyte containing 15% by weight of sulphuric acid showed that voltage, current density, and bath temperature are interdependent, and that therefore only the effects of forming voltage and bath temperature need be considered initially. Decreasing temperature results in greater unit barrier thickness. An experiment to establish the effect of electrolyte concentration on unit barrier thickness, when forming coatings at 15 V in sulphuric acid electrolyte at 21° C, showed that at constant voltage pronounced changes in current density occur with variations in sulphuric acid concentration, current densities being extremely low at very low and very high acid concentrations. No coatings were formed at high acid concentrations, apparently because there was insufficient water present to ionise the electrolyte and to form a coating. The investigations proved that the type of the electrolyte, its concentration, and its temperature control the solution rate at the bases of the pores and that temperature is the dominant factor. Furthermore, it was established that the conditions prevailing at the base of the pores are vastly different from those existing in the body of the electrolyte. Conditions at the pore bases are characterised by high temperatures and high electrolyte concentrations, both of which are necessary to account for the relatively rapid rates at which these coatings can be formed.

● *SILICON POWER RECTIFIER*

Because of the vast possibilities of semiconductor power rectifiers, major efforts are now being made to develop commercial types. In addition to germanium, silicon appears to be a semi-conductor which offers great promise. The major advantage of silicon is that it can be operated up to temperatures of about 180° C. It must be considered a remarkable achievement that it is now possible to produce silicon rectifier units with junction area as large as 0·05 cm^2, i.e., many times the *p-n* junction area of the older type. These new fused-junction units are prepared with *n*-type single-crystal silicon. Aluminium is used as the *p*-type impurity element which is fused to the silicon to produce the *p-n* rectifying junction. The completed unit is then placed in a housing of copper provided with radiator fins for dissipating the heat, which is due mainly to forward load current. Compared with the older type, the large-area silicon rectifier suffers from the disadvantage of having a higher leakage current; its forward d.c. characteristics are, however, quite good. Forward voltage drop has been found to decrease with operating temperature, and this effect is apparently greater at low values of load current. The effect of operating temperature upon rectification ratio is quite pronounced. Thus, while at room temperature the forward-to-reverse current ratio is in the order of 500,000, it decreases to 13,000 at 150° C, and to 3000 at 200° C. In the case of the type with a junction area of 0·05 cm^2, the heat-dissipating ability of the forced air cooled copper radiator permits the carrying of a maximum load current of some 15 A, corresponding to a peak leakage current of 20 mA. With natural-convection cooling, the same rectifier can handle a load current of 6·5 A average at 100-V peak potential.

● *DYNAMIC CHARACTERISTICS OF SILICONE RUBBER*

The unusual high- and low-temperature properties of silicone rubber make it a desirable material for vibration isolators which are to retain their serviceability at temperature extremes. In general, silicone cannot be substituted directly for natural rubber and neoprene in established designs. This lack of interchangeability results principally from the lower tensile strength and the unusual load-deflection characteristics of the material. A comprehensive investigation of the dynamic properties of silicone rubber has recently been undertaken for the purpose of providing information which would enable designers to utilise the new material to the greatest advantage. The data made available are derived from a study of the visco-elastic properties of silicone rubber under various conditions of strain, frequency, and temperature,



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against comparative data obtained for natural rubber. The equipment employed in this investigation was especially designed to measure as simply as possible the dynamic modulus of the material under conditions of strain, temperature, and frequency, with a high degree of accuracy. Essentially, the test apparatus consisted of a flexometer to deflect the test specimen through the desired amplitude, two strain-gauge pick-ups, and electronic gear to amplify and measure the signal produced by the pick-ups. A finding of importance is that the modulus of silicone rubber is markedly influenced by strains exceeding a certain limit. If the strain is increased above this limit, the load-deflection curve exhibits an abrupt reduction in slope. This behaviour is attributed to the rupture of various structural bonds, either between the polymer and the filler or between the polymer molecules. This structural breakdown is much greater than that exhibited by natural rubber and neoprene and, while in these materials the structure tends to rebuild partially if the material is allowed to rest, no such recovery was found to have taken place in the case of the silicone rubber.

● *ELECTRONIC COMPARATOR MICROMETER*

A novel comparator micrometer has been devised which is based on a new capacitance principle and is capable of measuring displacements as small as a millionth of an inch without physical contact, its full-scale deflection registering ± 20 micro-inches. In this instrument, the conversion of the capacitance variation to an electrical signal is accomplished by means of a new type of transducer element. This element consists of a small glass capsule filled with noble gases under reduced pressure and containing two electrodes. By exposing this element to a radio-frequency electric field between the plates of a capacitor, a relatively high direct voltage is set up between the two electrodes. According to the position of the element in the electric field, the magnitude of this voltage will vary between ± 60 V. In the actual instrument a variation of one thousandth of a millimeter in the position of the element in the high-frequency field is sufficient to produce a signal voltage as large as two volts, supplied to a differential circuit equipped with an indicating micro-ammeter.

● *RUBBER GEAR TEETH*

It is reported that the use of rubber gear teeth in couplings is proving very useful, as the resiliency of such teeth accommodates misalignment in drives and minimises transmission noise under irregular load conditions. In order to obtain the required strength of the gear teeth, replaceable rubber blocks are moulded in the shape of involute gear teeth and mounted over lugs on a driving spider, so that the power is transmitted from the spider *via* the rubber teeth to a mating driving ring with internal teeth. Angular and parallel shaft alignment, as well as shock, is therefore effectively taken care of by the resilient rubber teeth. Where the shaft speed falls within a critical vibration frequency range, the stiffness of the drive connection can be readily altered by varying the number of rubber teeth employed. Maintenance is facilitated, as the design permits the installation of new teeth without requiring dismantling.

● *DETECTION OF SLIP IN BELT DRIVES*

A recent patent specification describes a simple and effective apparatus for detecting the slip of a belt or rope drive relative to its pulley or drum. In this connection, it must be remembered that belt slip in underground belt conveyors for mines presents a very serious safety hazard, because belt slip may be, and has been, the cause of serious fires. The new apparatus consists of a tachometer generator driven by a driving drum, and another tachometer generator operated by frictional contact with the belt, the respective voltages generated by the two tachometers being utilised to indicate the presence of slip. By comparing the two voltages electrically, it is thus possible to obtain a direct indication of any such belt slip. A relay is provided to trip the driving motor when the slip prevailing exceeds a certain limit representing the danger point. Naturally, the application of this device is not limited only to the case mentioned above and it should prove very useful in many other plants for the purpose of eliminating waste of power and lengthening the useful life of belt or conveyor bands. In such cases, simple indication of belt slip will usually be sufficient, so that the special motor-tripping device will not be required.

● *ULTRASONIC REMOVAL OF MARINE GROWTHS ON SHIPS' HULLS*

The serious effects of marine growths on the speed and power consumption of ships of all types can hardly be over-emphasised. Instead of relying on the growth-inhibiting effect of chemicals added to paint, proposals have been made to utilise the action of ultrasonic vibrations. In fact, the suggestion has been made to utilise mechanical vibrations of the hull and its natural frequency to diminish the surface tension of the surrounding water and with it the skin friction of the hull of the vessel. Such vibrations would, it is claimed, have the additional effect of eliminating barnacles and marine growths, since the intense supersonic vibration would loosen any growths already present and would also prevent new growth. A recent patent describes what is claimed to be a particularly effective method of producing molecular vibration within the ultrasonic range of the material of the hull, as differentiated from a vibration or pulsation of the hull itself. According to the invention, a transducer or a number of transducers for generating the ultrasonic vibrations is arranged parallel to the inner surface of the ship's hull, to which it is

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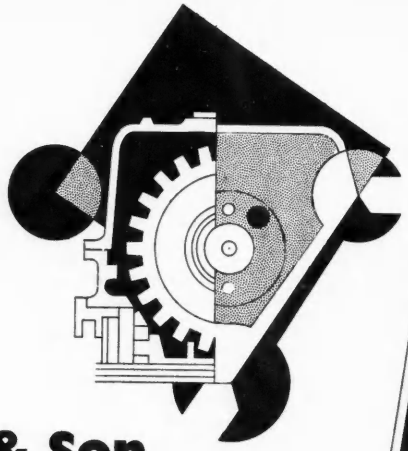

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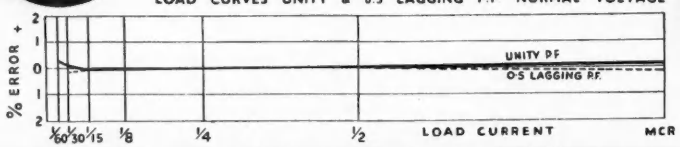

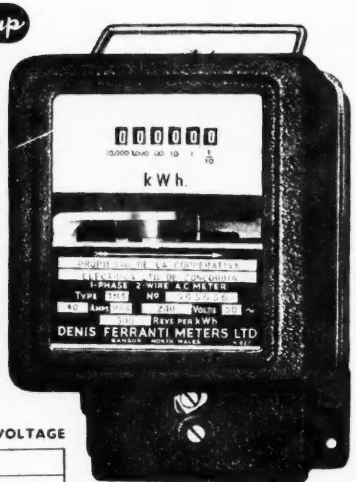

Illustration shows metal-cased meter with cyclometer register. Pointer registers and moulded cases can be supplied.

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rigidly attached. The inventors state that, although the theory is not fully understood, this method of mounting the transducers is particularly effective. By mounting them parallel to the hull and by rigidly associating one or both ends of the transducer or transducers with the hull, the ultrasonic vibrations generated are caused to be conducted into the hull with a minimum of attenuation and therefore effectively arrest the tendency of marine growths and organisms to attach themselves to the bottom of the hull. As mentioned above, it is worthy of note that the inventors lay stress upon the fact that their system does not require a mass vibration or pulsation of the hull to obtain the desired protection.

● *SMALL TRANSFORMER PRODUCTION TECHNIQUE*

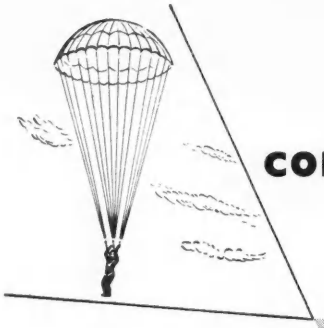
A most interesting technique for the production of small transformers for electronic purposes, such as audio-transformers, has been developed. The new technique is based on the idea that, by slicing or cutting a wound laminated foil or rolled sheet material into cross-sectional wafers, it is possible to produce individual coils with close spacing. In fact, wafer slices with spacings as small as 0·0002 in. and conductor areas measuring 0·0009 × 0·00017 in. have been produced by this method. It is obvious that, by means of this technique, a great number of turns can be packed into a small area, while a wide range of equivalent wire sizes can be obtained simply by varying the wafer thickness when slicing. It is reported that in this way audio-transformers of the same size as conventional units have been constructed with aluminium-foil wafer coils. It is suggested that a further reduction in size can probably be made by using copper foil of 0·0002 in., which is not, however, at present commercially available. In electrical respects the frequency response and other electrical characteristics of wafer-type coils do not differ from those of the conventional wire type. The construction of a wafer coil is initiated by winding wide metal foil into a roll. This foil is previously coated with an adhesive-type insulator, or alternatively a spacer is used to separate the turns. Terminal tabs, in the shape of tubes or tinned copper coil, are attached at the beginning and end of the winding, or the foil itself is folded into a terminal tab. Slicing of the roll is carried out in a lathe-type cutter, using either a straight blade or a rotating circular blade.

● *PLASTIC-METAL LAMINATE*

By bonding sheets of plastic and steel, thus combining the attractive surface properties of a plastic material with the mechanical strength and rigidity of metal, a new structural material is formed which should find widespread uses. Plasticised polyvinyl chloride appears to be a most suitable material for supplementing its properties by a metal backing, since it resists abrasion, corrosion, and the effects of heat, light, and weather. Laminates made with polyvinyl chloride sheet will maintain dimensional stability up to 250° F and will not support combustion. It is claimed that, by means of an adhesive under heat and pressure, vinyl sheets can be applied to any flat surface of steel, aluminium, or magnesium. Bonding to copper and other metals and alloys is also claimed to be possible. Non-metallic materials can be bonded with vinyl sheet by similar methods. The four prerequisites for producing a satisfactory laminate are proper metal surface preparation, the right type of adhesive, and suitable vinyl formulation and bonding temperature. In hydraulic-press bonding, a sheet of polyvinyl chloride is mounted on the dried cement-coated metal surface and the assembly placed in the press. A typical bonding cycle, including the heating and cooling periods, carried out in a multi-platen press, will require less than half an hour. Where the roll method of bonding is used, the metal is degreased, rinsed, and acid-etched, in order to roughen its surface. An adhesive in solution is applied directly to the metal surface by roll coating. The adhesive is dried by passing the sheets through a hot-air oven at 175 to 250° F, and the adhesive coat is subsequently set up in an electric oven to the proper state of tackiness. The sheet is then ready for rolling on vinyl sheeting at room temperature by means of rubber rollers exerting a pressure of some 25 to 35 psi.

● *IMPROVING FATIGUE PROPERTIES OF FLAKE GRAPHITE AND NODULAR GRAPHITE CAST IRONS*

Apart from some work on crankshafts and a number of tests on pearlitic cast iron (as reported on p. 452 of our issue for December, 1953), little published information is available on the effect of surface rolling on the fatigue strength of cast iron. The data recently released on the effect of surface rolling on the fatigue strength of 45-deg. V-notched specimens of flake graphite and nodular cast irons will therefore prove valuable. The conclusions arrived at by the investigators are that the fatigue limits of flake graphite and nodular graphite cast irons are definitely increased by surface rolling. The increase in fatigue limit actually obtained will depend upon the ability of the material to absorb cold work without developing surface failure; in this respect nodular cast irons have been found to be superior to flake graphite cast irons, and ferritic irons superior to pearlitic irons. Increases in fatigue limits of about 20% in a pearlitic flake graphite cast iron, 110% in ferritic flake graphite cast iron, 140% in a pearlitic nodular cast iron, and 190% in a ferritic nodular cast iron were obtained. The results indicate that the beneficial effects of surface rolling are two-fold. The fatigue limit and the fatigue life at stresses above the fatigue limit are increased. This is important, since it is not always necessary to



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design at stresses below the fatigue limit, and to allow for infinite life in fatigue. In such cases, rolling will have a very beneficial effect, because it will permit much higher stresses to be used than would be safe in untreated material. A treated part subjected to bending fatigue will also be able to withstand occasional high overstresses which would quickly cause failure in an unheated part.

● *CONSTANT-FORCE SPRING*

There are many cases in which a mechanism requires the incorporation of a spring which, when being compressed, exerts a constant force independent of the degree of deflection. Where small forces are concerned, this problem can easily be solved by means of a specially shaped spring, resembling a helical extension spring in appearance and exerting a force when flexed under load. In operation, compression forces are applied through arms on the end of the helically wound spring body. As the arms are moved together, the spring body buckles out, changing the wire stress and the effective moment arm of the spring force. Since the reacting force at the spring arm is a function of the wire stress and the moment arm, the dimensions of the spring body can be so selected as to provide a resultant force which increases, decreases, or remains substantially constant with deflection, as may be required. The useful deflection range of the spring-arm ends is normally considered to extend from the relaxed position to one in which both arms become parallel. This range will be found to produce a slight variation in load. However, by limiting the deflection range in operation, the spring action can be made to yield a practically unchanged load variation in the operational range.

● *PRODUCTION OF HIGH-STRENGTH SINTERED-POWDER PARTS*

A novel patented technique makes it possible to produce from metal powders steel parts which have high density and combine hardness, strength, and ductility to such an extent that they approach very closely the properties of a wrought material. The steels produced can be heat-treated to yield a wide range of hardness and tensile properties. Obviously, the most important single factor in attaining such mechanical properties is a high density ratio, i.e., low porosity; for the new process, density ratios well above 98% are claimed. Below a threshold ratio of 97%, elongation and reduction in area, as well as impact strength, were found to decline very sharply, although tensile strength is less severely affected. To obtain the required high density ratio, the iron powder should be annealed soft and should not contain more than 0·3 to 0·5% non-iron ingredients. The carbon content should not be over 0·15% and undissolved inclusions should not exceed 1% by volume. These requirements are met by annealed electrolytic iron powder. In order to secure good heat-treating properties, a small percentage of ferro-manganese powder is included. As it is necessary to avoid oxidation of the manganese in the sintering stage, such oxidation having a harmful effect, a certain amount of powdered graphite is also added. The percentage of graphite required is governed by the oxygen content of the iron and the final percentage of carbon wanted in the material after sintering. Where highest mechanical strength is required, the graphite content is so chosen that the carbon content after sintering does not exceed 0·1%. This leaves the material soft enough to permit repressing to the highest density and, where required, the carbon content can then be increased by gas carburising.

● *ROLL CLADDING*

A process has been developed for producing multi-layer metal tubes made of light metals as well as other metals. With this method, tubes extruded closely on top of each other are subjected at welding temperature to uniform welding pressures and diameter reduction in a radial, rotating tube-reducing machine with a quick-swaging action. Compared with rolling, this method is said to guarantee a more uniform welding pressure and therefore uniform welding over the whole tube. It is applicable even for metal tubes of low heat strength, as the tubes are not subjected to stress. The forces exerted by the hammering are very high and, owing to the rapid sequence of such hammering, the metals cannot escape the welding pressure. Finally, the hammering effects destruction and removal of oxide layers present between the tube layers. This method is also applicable for producing wires from a massive wire core and a tube sheathing.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

In this connection, it has sometimes been suggested that we should include full references regarding the source, etc. of items in this Section. Our reason for withholding these details in the first instance is that, as a result of letters received from our readers, we are better able to assess the kind of information which appears to be most required at any given time, thereby influencing our editorial policy of selection. When answering enquiries, however, the above details are invariably included.

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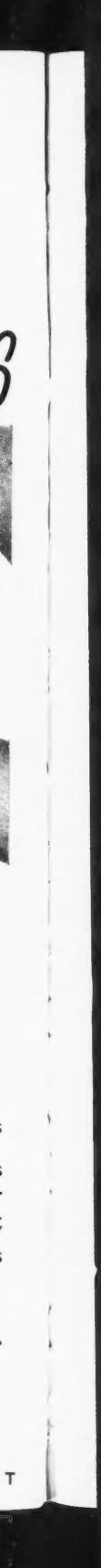

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The Inspection and Overhaul of Turbo-Generators

By E. J. Pohl. (From *Maschinenschaden, Germany*, Vol. 27, No. 7/8, August 1954, pp. 90-101, 15 illustrations.)

It is generally recognised that regular inspection and overhaul of turbo-generators are indispensable, but the intervals between these periods naturally varies according to the size and design of the machines, operational conditions, e.g., whether they are run as base-load or peak-load machines, and other factors. Apart from these special considerations, the lessons of past experience are sufficient to indicate at what point the internal condition of a plant will render overhaul most profitable. It is also possible to assess the minimum extent of such overhaul which cannot be reduced without risk.

In Great Britain, overhaul of plant of the latest design, run as base-load machines, is carried out at intervals of three years. In the U.S.A., overhaul intervals of four and even six years are scheduled for the largest units, the turbines being equipped with special instrumentation and the dielectric losses of the generators being measured. In addition, it is claimed that American designs are particularly robust, because their length is 40 to 50% less than, for example, British designs. In a number of specific instances, the special instrumentation installed is reported to have given timely warning of defects, but naturally it still remains to be seen whether such instrumentation will make it possible to cover the long operating periods proposed without overhaul. In any case, it is an open question whether it is not better to prevent damage by means of more frequent overhauls than to wait for the warning signals provided by these instruments, which, while perhaps capable of averting major damage, cannot prevent interruptions in power production, these being the more inconvenient the larger the unit concerned.

The three-year maintenance schedule customary in British power stations has also been observed in Germany. The large sets at Zschornewitz Power Station, for example, used to be dismantled for inspection at similar intervals before the war. Swiss experts also consider this interval as technically justified, though they propose to reduce it to two years or even to twelve months where the turbine is operated with steam at temperatures exceeding 930° F.

Small installations require more frequent overhauls, and for normal industrial turbines a maximum interval of two years has been recommended, irrespective of the number of working hours, though in Britain an annual overhaul has become accepted practice for this type of turbine. In Germany, most installations are given an overhaul every two years, a period presumed to cover 9000 working hours and, in some cases, up to 15000 hours. For stand-by plants with 1500 or less working hours per annum, the interval is three years, provision being made to inhibit corrosion of the turbine during idle periods. In industries with special working conditions, such as the sugar industry, annual overhauls have become customary. The advisability of such frequent overhauls has been borne out by the retrospective evidence of the war years and immediate post-war years, when neglect led to increased breakdown incidence.

An extension of the operating period is now aimed at, because, with the introduction of high-pressure steam, overhaul has become more cumbersome and difficult. However, it is precisely in such plant that a careful watch must be kept on the internal condition of plant, so that the three-year period should not be exceeded.

Overhaul can be expected to prevent or mitigate damage, such as that shown in Figs. 1 and 2, only in connection with processes which develop gradually, the aim being to make such processes amenable to control. One such process is surface deterioration, with consequent reduction in fatigue strength.

The same effect has been observed in spring brass which had become zinc-impoverished. In the transition region between the sound and the unsound material, a notch effect develops, and this is responsible for crack formation. The processes in question have been reproduced in the laboratory and, by applying the Wöhler test to both sound and artificially de-zinced material, it has been found that the latter's fatigue strength amounts to only 60% of that of the sound material, as shown in Fig. 3.

That the properties of a material may also be seriously affected is evidenced, for example, by the behaviour of bolts whose impact strength diminishes as a result of various factors, giving rise to brittle failure. Another outcome of internal processes, at elevated temperatures, is deformation of the material if its endurance limit is exceeded. The rate of creep under a certain stress is characteristic of the material and determines the period between overhauls.

Fig. 1. **Pitted blades and shrouding of a wheel in the high-pressure cylinder of a steam turbine.**

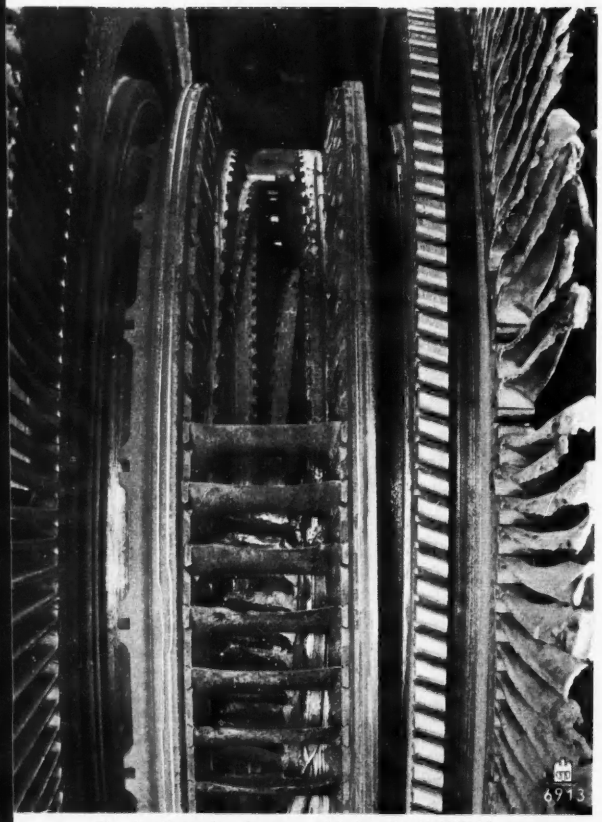

Fig. 2. **Extensive damage to blades of a 40-MW Ljungstrom turbine, due to rupture of an expansion ring as the result of corrosion.**

The effects of fatigue and creep on the efficiency of turbo-generators can be roughly assessed, because they are related to the time factor. It would therefore appear tempting to produce lighter machines by basing their design on a shorter life, enabling them to be subjected to higher stresses. The position with regard to overhaul intervals would then be quite clear. However, experience shows that present designs also do not last indefinitely, and eventually become liable to breakdown, though examination of the material of old equipment has failed to reveal any comprehensive reason for its "decrepitude." Nor is the number of working hours a reliable guide for the assessment of risk, for some installations are still in full commission after three or four times the number of working hours of other installations which can only be described as defective. On the other hand, peak performances are naturally the most exacting and must be evaluated on a higher scale. This, of course, does not refer to the designed full load; mechanical and thermal changes produced in the turbine and generator by starting and stopping entail far greater stresses, while even the briefest overloading of the generator insulation may age it by several years. Concepts like thermal fatigue and thermal shock help to elucidate the influences to which the structural parts are exposed during operation, and it would therefore seem appropriate (whether design were based on "duration" or "durability") to adopt a "weighted working hour," i.e., time multiplied by a coefficient reflecting the severity of the task to be performed.

At the moment, metrology is not sufficiently far advanced to permit squeezing wear-and-tear into one suitable diagram; hence, its influence on overhaul periods must be considered separately in each individual case, preferably on the basis of the behaviour of installations of similar design or service and on a statistical survey of their histories.

Fig. 4 shows the incidence of defects in 769 turbo-generators over a period of five years. The total number of defects was 1132, but all these defects occurred in only 463 of the turbo-generators, amounting to from 1 to 11 defects each. The diagram also shows the relative proportion of the repair costs incurred during the five years for each installation. Statistical surveys of this kind will reveal whether the incidence of defects is due to a particular structural part or to deterioration of the installation as a whole, and should be of use in determining periods between overhauls.

Planning of Overhauls

A preliminary examination will show the location of potential sources of failure, while further guidance may

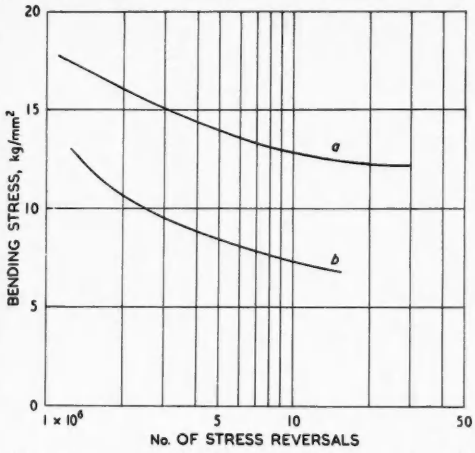

Fig. 3. **Comparison of fatigue strength of** (*a*) **sound and** (*b*) **artificially de-zinced brass.**
Material, Ms63; composition 63% Cu, 3% max. Pb, remainder Zn.

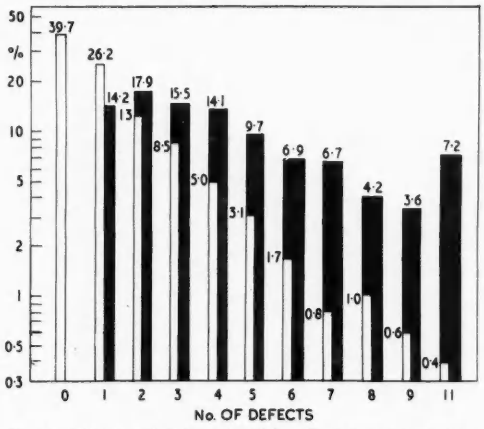

Fig. 4. **History of defects in 769 turbo-generators over a period of five years.**
White bars indicate percentage distribution of the total of 1132 defects.
Black bars indicate percentage distribution of the total repair costs.

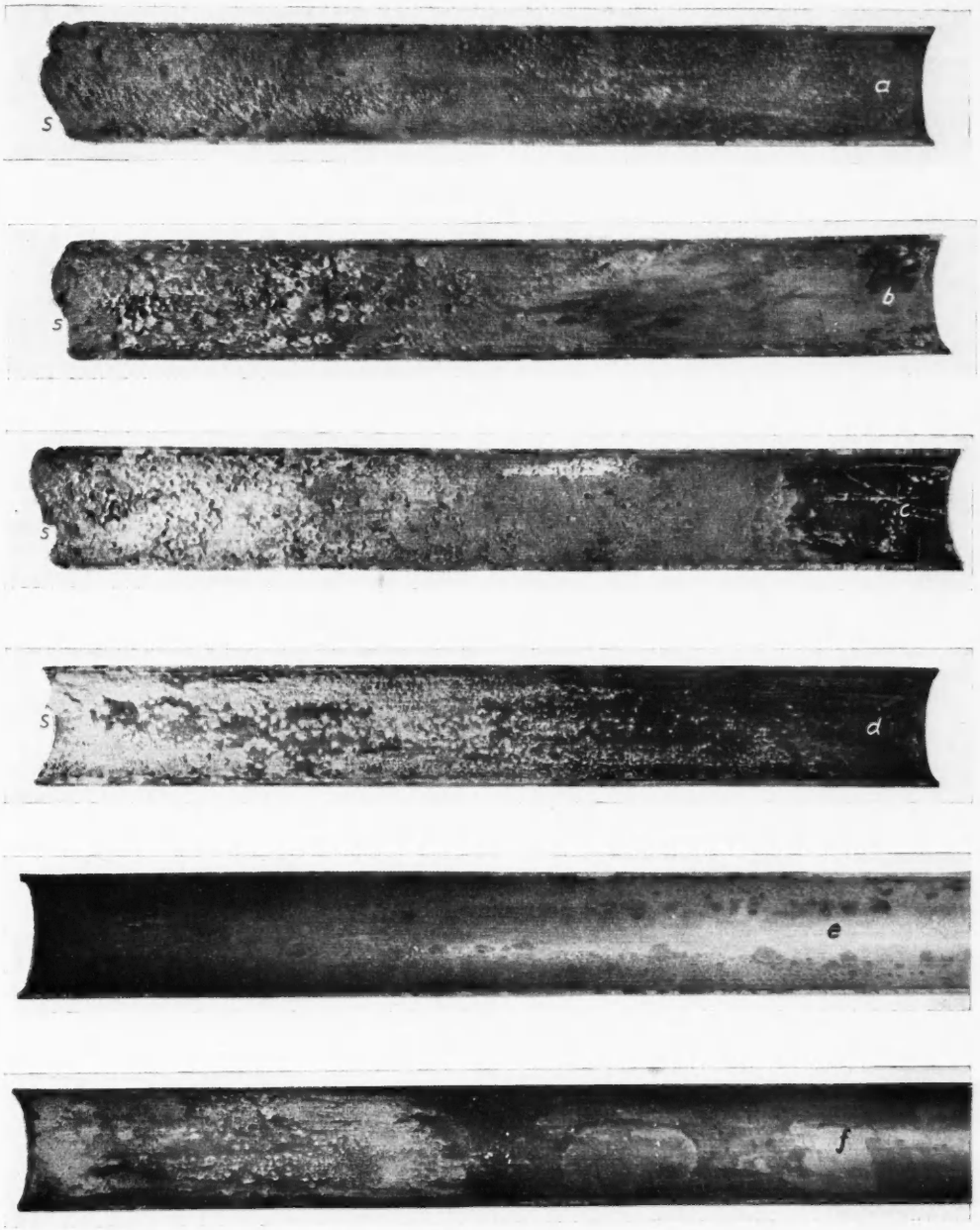

Fig. 5. **Corrosion of Ms63 condenser tubes in saline solutions by experimentally produced stray currents.**

	Voltage, V	Amperage, mA	Cooling water, NaCl concentration, milligrams/litre	Duration of experiment, hr
(*a*)	7	20	5000	70
(*b*)	7	5	500	290
(*c*)	4	2	500	385
(*d*)	4	0·8	50	335
(*e*)	0·5	0·3	50	72
(*f*)	4	0·8	50	72

be obtained from records of the plant's past history and of unusual occurrences. For example, a past trouble in the boiler plant which has affected steam supply to the turbine will indicate the need for a special examination of the steam passages, so that certain parts which would otherwise not be examined will have to be dismantled. Knowledge of the history of plants of similar design in other power stations is of particular value, because it may lead to the precautionary measure of ordering certain spare parts well in advance.

For the work of dismantling and re-assembly, it is advisable to obtain a competent turbine fitter from the manufacturers of the plant. At the same time, even with installations of identical design, each unit may have its own peculiarities, which can be catered for only on the basis of experience, as, for example, labyrinth-gland and blade clearances. Overhaul should therefore be supervised by an employee of the power station, whose task will be to prepare a careful record of the work to be done.

Dismantling must be sufficient to permit inspection of all parts exposed to wear or deterioration, and must not be confined to rotating parts only, as apparently stationary parts can be displaced under the action of heat and can also be damaged. Moreover, in the course of time, rust developing between loosely connected parts may cause damage through expansion or binding, while powerful stresses leading to cracks in the casings may also arise from distortion and creep.

The maintenance engineer should start his examination of components before they are cleaned; thus, for example, blade deposits may provide valuable indications of existing defects. Since examination of all parts would involve excessive expenditure of labour, selective limitation is necessary, and this must be left to the experience and judgment of the maintenance engineer.

As an example, Fig. 5 illustrates damage occurring in condenser tubes in saline solutions, as a result of the effects of experimentally produced stray currents. It will be noticed that all tubes are covered with corrosion products, and there are signs of erosion at *S*, on the side facing the cathode. This is particularly pronounced at the end of specimen (*a*). As was to be expected, erosion decreased with a decrease in current intensity, so much so that, at 0·8 mA, only traces of erosion could be observed. The amount of green corrosion products also decreased.

For a correct evaluation of a large-scale overhaul, a certain continuity is indispensable, and in this connection overhaul report forms, based on practical experience, have been issued, and these afford useful guidance. The overhaul of some of the items in one of these report forms is discussed below.

Diaphragms:—

As diaphragms may distort during the period of operation, dismantling of these parts becomes more difficult the longer it is delayed. Nevertheless, without dismantling, a complete examination, even with the aid of a mirror, is impossible, owing to the confined space in which the rotor runs, so that even major defects, such as those shown in Fig. 6, may escape detection if they happen to be located in not readily accessible positions.

Distortion of casings:—

Temperature changes during starting and stopping, as well as during operation, produce temperature differences in the casing walls, and the resulting stresses can lead to deformations which may become dangerous where clearances are small. It is therefore important to keep clearances under supervision.

Bolts:—

Bolts must be carefully examined at each overhaul. In the older turbines with low design stresses, bolt breakage is generally due to faulty material or assembly.

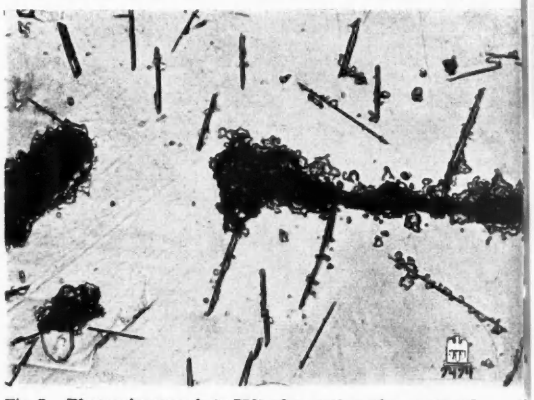

Fig. 7. **Photomicrograph (× 750) of a section of a ruptured bolt after 80,000 working hours.**

Fig. 7 relates to a bolt, the material of which became brittle after 80,000 working hours, at a temperature of only about 570° F, because of a high nitrogen content; as shown in the illustration, the structure is riddled with nitride needles. At high operating temperatures the possibility of dangerous rupture of bolts and studs is particularly great (Fig. 8). Embrittlement first causes a crack at the base of the first thread, in view of the notch effect prevailing at that point, and the crack may extend right through the bolt. In any case, bolts are subjected to additional stresses through thermal influences, and the importance of correct bolt design is emphasised by the consideration that simultaneous rupture of a number of bolts may lead to a considerable escape of steam. Furthermore, bolts may be subjected to abnormal stresses as a result of excessive tightening.

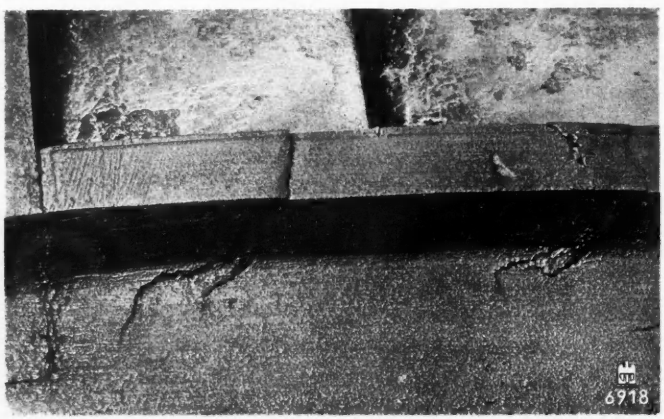

Fig. 6. **Cracks between guide blades and guide ring.**

Steam strainers:—

Strainers must be in perfect condition, so that no foreign bodies can be carried by steam flow into the blading. Strainers, rotted and with large holes in them, have repeatedly been found, the missing fragments having already reached the blading. Where the perfor-

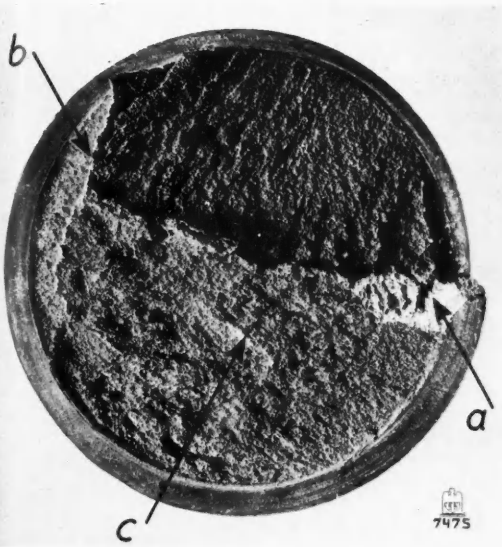

Fig. 8. **Fracture of a stud after 15,000 working hours.** Most of the fractured surface is grey, i.e., only the light zones at (*a*), (*b*), and (*c*) have held the parts together.

ations are blocked with dirt, the strainer may be either compressed or torn open (Fig. 9), according to the direction of steam flow.

Oil-cocks:—

All oil-cocks in the circuit must be secured against improper operation, so that the oil supply to bearings and control devices cannot be interrupted. This risk is also present in turbines with several oil coolers. If switch-over during operation is unavoidable, the switching mechanism must be foolproof. It is also possible to instal an automatic valve-controlled by-pass, to ensure an oil supply for the bearings in case an oil cooler is inadvertently shut off before another is in operation.

Generator stators:—

Opening up the generator does not afford a complete view of the stator windings, as many parts are hidden or are not easily accessible for observation; special apparatus for this purpose must therefore be employed.

Little can be learned about the condition of the insulation by sight or touch, but megger tests will give an idea of short-circuiting or of excessive leakage from the windings to the casing. Measurement of insulation power factor provides a somewhat more accurate picture of the quality of the stator insulation, but is of value only if it is first carried out when the generator is new, and then repeated at frequent intervals for purposes of comparison.

Knowledge of Test Procedures

Maintenance engineers must possess a profound knowledge of the equipment available for ascertaining the precise condition of a structural part. Thus, for instance, where a crack is suspected, it must be located and its extent determined by means of non-destructive tests with which the engineer must be familiar. It may even be sometimes necessary to evolve new procedures or to adapt existing ones for the same purpose.

For example, when overhauling Ljungstrom turbines, it is necessary to examine for cracks the lagged steam-inlet pipes traversing the exhaust casing and through which live steam enters the steam chests. Experiments with damaged pipes have yielded a method whereby the pipes in question can be adequately examined without dismantling or removal of the lagging.

Distribution of Defect Incidence

Overhauls and the repair of defects occurring during operation indicate the distribution of defect incidence among the individual components of turbine, condenser, and generator. Statistical treatment of these data serves as a guide in carrying out subsequent overhauls and also suggests to manufacturers and operators possibilities of improvement.

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Fig. 9 (below). **Tearing of steam strainer as a result of blocked perforations.**

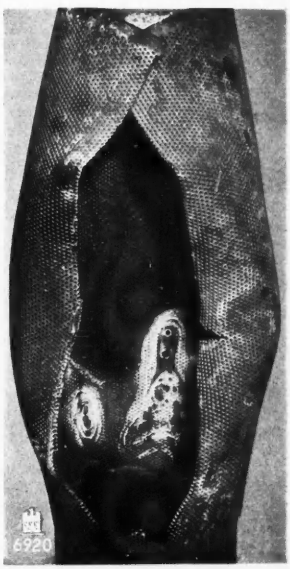

Table I. Distribution of defects in various components of turbo-alternators.

Location of defect	Percentage distribution of 224 defects found during overhaul in the course of one year	Distribution of 1112 defects found during operation	
		According to numbers, %	According to repair costs, %
Steam Section:—			
Rotating blades	32·6	22·0	22·4
Guide blades and diaphragms	8·0	2·9	2·3
Shafts, wheels, and drums	1·8	4·3	4·7
Journal and thrust bearings	15·2	8·1	4·6
Diaphragm glands and balance pistons	14·3	5·9	3·1
Casings	4·0	5·6	2·4
Valves and control gear	3·1	3·7	7·4
Miscellaneous	2·2	6·0	2·7
Total	81·2	58·5	49·6
Electrical Section:—			
Rotor	2·7	15·5	24·8
Stator	14·7	10·1	19·8
Exciter	0·5	3·7	0·5
Miscellaneous	0	2·3	1·7
Total	17·9	31·6	46·8
Condenser (excluding tubes):—			
Prime movers	0	1·2	0·2
Pumps	0	1·3	0·2
Miscellaneous	0	0·8	0·1
Total	0	3·3	0·5
Oil-Supply System:—	0·9	6·6	3·1

CANADA

Air-Bubble Curtain for Cushioning Blasting Operations

By R. C. JACOBSEN. (From *Ontario Hydro Research News*, Vol. 6, No. 2, April/June 1954, pp. 14-18, 33, 6 illustrations.)

THE forebay junction between the old and new canals of the water-power developments of the Hydro-Electric Power Commission of Ontario at Niagara Falls was achieved by blasting the rock barrier at the selected location. The block of rock was approximately 48 ft deep, over 100 ft wide, and averaged about 50 ft front to back. More than 6 tons of explosives were used to shatter this block. The feat was remarkable in that it was accomplished without interruption or damage to the existing Niagara Power Station No. 1, the nearest section of which was within 100 ft of the exploding charge.

In planning the blast it was realised that, unless suitable precautions were taken, water-borne pressure waves created would probably cause damage to the power house. The blasting operation was made possible by the use of an air-bubble curtain which effectively attenuated the hydraulic shock produced. This is the first known instance of the successful use of air as a barrier to block such shock waves.

Preliminary experiments showed that the reduction of the pressure waves depended only on the quantity of air used and not on the number of parallel perforated tubes laid at the bottom of the experimental tank. It was further shown that the attenuation appears to follow a law similar to those which govern other forms of attenuation of wave energy by varying amounts of absorbing matter such as, for example, Beer's Law for the absorption of light in colour solutions. For the air-bubble curtain the relationship can be conveniently expressed as:

$$\log_{10}\frac{P_a}{P_o} = KQ$$

where P_a and P_o are the respective pressures with and without absorption, and Q is the quantity of air supplied per unit length. In the trial tests, K proved to be -4 when the pressures were expressed in psi and Q was measured in cubic feet per second of free air per foot of curtain. This value revealed that the use of only 15 cubic feet of air per minute for each foot length would reduce the pressure transmitted to one-tenth of the full value.

The air-bubble curtain installed in the forebay at Niagara Generating Station No. 1 was arranged in three straight portions, one of which was located 50 ft in front of the plug face, and the others at 45 deg. to the rock bank. This layout was adopted to permit "mucking out" the rock if removal of the plug in small sections proved to be necessary. The piping was prepared in two sections, because a total length of nearly 320 ft was required. Each section of the air curtain was controlled through separate valves, while orifice plates and pressure gauges measured the quantity of air used.

To form the air bubbles, two rows of 0·04-in. holes, spaced an inch apart, were to be drilled in the sections of aluminium pipe. However, frequent breakage of drills was unavoidable in providing nearly 24,000 holes in thick-walled pipe. To determine whether the hole size could be increased, and a shortage of 0·04-in. drills alleviated, auxiliary tests were made in a glass-sided tank in the laboratory. Results indicated that the limiting hole diameter for satisfactory bubbles is about 0·055 in.

The air curtain was thoroughly tested. High-speed pressure gauges, similar to those used in the preliminary tests, were installed at the various penstock intakes, and at the Gibson-test tap of one penstock. Initially, small dynamite charges were fired in the forebay near the centre-line of the plug. Detonations were first conducted with 0·5-lb charges, which were gradually increased to 4 lb; pressure shocks up to 34 psi were recorded at the intake of unit No. 3.

With the air curtain in use, similar charges produced no measurable effects, although the gauges were sensitive down to 0·5 psi. When the charge was raised to 15 lb, a shock of 1 psi was registered. Without the air curtain, a pressure shock of about 70 psi would have been expected. As a further step, holes were drilled in the rock plug within about 2 ft of the water, and loaded entirely below water level with charges ranging from 45 to 120 lb. When the air curtain was used, these produced no measurable pressures, whereas a charge of 105 lb fired without the curtain, produced 55 psi at No. 3 intake. Hence, it is apparent that 1 lb of dynamite detonated directly in the water produced approximately the same pressure as 10 lb detonated in the rock only a few feet from the water.

The groups of charges required for blasting large masses of rock are now usually fired with delays of 25 to 75 milliseconds between them. The suggestion was made that the air bubbles might be collapsed by a first shock wave and be of little use to attenuate shock waves produced a few milliseconds later. To test this possibility, some charges were fired in pairs with such a delay, to simulate a typical blast. Results from these test shots indicated that no measurable shock waves penetrated the air cashion.

Complete records of the hydraulic pressures and seismic shocks were obtained during the advance operations. Because the results were promising, it was decided that the plug could safely be removed in one major blast, with the limitation that the amount of powder placed in each group of the delay series would not exceed 1000 lb. The anticipated rock-borne shock was the limiting factor in determining this weight of powder, since only hydraulic shock would be reduced by the air bubbles.

When the blast was eventually fired, the hydraulic pressure waves registered at the generating station reached a peak of 15 psi and the seismic displacement was 0·08 in. horizontally and 0·04 in. vertically. These values were both a little higher than those predicted; however, subsequent frame-by-frame analysis of high-speed motion pictures of the blast indicated that, because of shock propagation, the nearer trim holes were fired along with most of the leading charge. Consequently, the quantity of powder exploded in the initial stage of the blast totalled about 1700 lbs, instead of the specified 1000 to 1100 lb in each delay. It may be noted that both hydraulic pressure and seismic shock increase in proportion to the square root of the amount of powder used.

An air-bubble curtain was also used in the tail-race of the new station to protect the draft-tube structure during the removal of the cofferdam. The equipment was constructed in a number of independent sections, of which only those necessary operated during any one blast. This procedure was followed because only small sections of the plug were removed at one time. The pipes were buried under 6 ft of 1½-in. crushed rock, which was placed near the tail gates as a shield against large pieces of rock displaced by the blasting or during subsequent rock removal. This barrier also served to exclude rock from positions from which removal by power shovel would present much difficulty. The crushed rock permitted a satisfactory flow of air bubbles and was sufficiently fine to be subsequently washed away by the turbine discharge.

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A Low-Alloy Cr-Mo-Ti-B Steel for Use up to 1200° F

(From *Metal Progress*, Vol. 66, No. 6, December 1954, pp. 84-89, 5 illustrations.)

Following the discovery that boron and titanium together confer remarkably high strength on low-carbon steels, further investigation has resulted in a semi-commercial boron-treated Cr-Mo-Ti low-carbon steel with creep and stress-rupture properties superior to those of stabilised 18-8 *steel, at least at temperatures up to* 1200° F *and for periods up to* 100 *hours.*

IN 1949, Comstock called attention to the remarkably high strength conferred on low-carbon steels by boron and titanium, or boron and columbium. Similar additions of titanium (about 0·30%) and boron (0·02 to 0·03%) also strengthened chromium-molybdenum steels, heat-resistant chromium steels, and austenitic chromium-nickel steels—all very low in carbon (0·07% or less). Furthermore, this high-temperature strength is due to *both* titanium and boron.

As Comstock's discovery of this titanium-boron effect indicated the possibility of producing a new low-alloy steel sheet for such high-temperature services as tail cones and combustion chambers for jet engines, Cornell Aeronautical Laboratories were asked to undertake further investigations.

A considerable number of 30-lb heats of titanium-boron steel was made, to reveal the influence of variable composition, and a 600-lb heat of supposedly optimum analysis was produced under commercial conditions.

The large heat was melted in an induction furnace and deoxidised by aluminium; ferro-titanium and ferro-boron were added and the heat poured into an 8-in. square ingot, 3 ft high. This ingot was forged to a 1-in. slab, about 8 ft in length, and subsequently rolled and cross-rolled to a 0·090-in. sheet, about 20 in. in width. All hot work was carried out at 1850° F max. Subsequently, this sheet was rolled at 1850° F to thinner gauges (0·030 to 0·075 in.) for the various tests. Sound sheet was thus produced with no particular difficulty, and the results of high-temperature tests—creep and stress-rupture—agree with those from corresponding 30-lb laboratory heats. Test results from small heats may therefore be accredited.

Chemical analysis of this 600-lb mill heat gave 0·065 C, 0·34 Mn, 0·28 Si, 2·91 Cr, 1·06 Mo, 0·14 Ti, and 0·022 B. The Ti/C ratio is a matter of considerable importance and was given much attention in the Cornell University investigation. At least 0·05% carbon is necessary to form austenite when soaking at hardening temperature and to harden the metal in subsequent cooling. The prime actions of titanium are to restrict the gamma field and to lock up carbon in a stable carbide. Therefore, if titanium is too high in relation to the carbon, the steel is ferritic at all temperatures up to 2100° F. This effect is shown in Fig. 1 for three boron-treated steels, each containing about 0·08% C, but with varying titanium content, all air-cooled after heating in hydrogen at 2100°F. Note that the hardness decreases progressively as the titanium (and the Ti/C ratio) increases.

Extensive creep and stress-rupture tests resubstantiated the conclusion that, when the titanium is somewhere between two and five times the carbon, the steels are air-hardenable, resist softening by tempering up to 1200° F or more, and have superior creep and stress-rupture properties. Similar studies showed that boron content could vary from 0·010 to 0·10% without significantly affecting high-temperature strength. This was surprising, because, as boron increases beyond about 0·04%, an unknown constituent appears at grain boundaries. The acicular ferrite matrix remained normal; expected hot-shortness was not observed; likewise, the sheet had good ductility in reverse bending at room temperature. Evidently, then, the boron addition need not be regulated or limited with high accuracy.

SEMI-COMMERCIAL PRODUCT

The composition for the 600-lb heat was chosen after some 30 compositions varying in carbon, titanium, and boron had been melted in 30-lb laboratory heats and their properties surveyed. The 3% Cr, 1% Mo basic analysis finally chosen approximates one of Comstock's steels, which was unbroken after 3300 hr at 1100° F and 30,000 psi, even though it had elongated 2%. The chromium is intended to increase oxidation resistance, and the molybdenum to increase hardenability and especially to decrease "temperability" and creep at high temperatures. Silicon at 0·28% represents the usual content for constructional alloy steels; the manganese of 0·34% retained from the melting stock is on the low side but is ample (with the titanium) to take care of incidental sulphur. Boron at 0·022% is a normal residual after boron treatment, and the combination of 0·065% carbon and 0·14% titanium (ratio 2·2) appeared about correct.

The metal possessed the metallurgical characteristics predicted by the preliminary work. Several 1-in. square specimens of 0·050-in. sheet were quenched from various temperatures with the following results:—

0·08% C, 0·27% Ti B.H. = 96 | 0·09% C, 0·94% Ti B.H. = 88 | 0·08% C, 1·65% Ti B.H. = 65

Fig. 1. **Change in microstructure and hardness with increase in Ti/C ratio in boron-treated steels. Nital etch, × 500.**

1700° F B.H. = 109 1900° F B.H. = 106 2100° F B.H. = 107

Fig. 2. **Microstructure of 3% Cr, 1% Mo, 0·065% C, 0·14% Ti, boron-treated steel after normalising at 1700°, 1900°, and 2100° F. Nital etch, ×500.**

Quench	Hardness	Quench	Hardness
1300° F	B-77	1575° F	B-92
1350	B-78	1600	B-96
1400	B-77	1650	B-101
1450	B-71	1700	B-106
1500	B-68	1800	B-108
1550	B-78	1900	B-107

Full hardness is obtained in a quench from 1700° F. If the steel is normalised at higher temperatures, there is doubtless a more complete solution of carbides (Ti, Cr, Mo, or complex), but this does not show in the as-quenched hardness; the most evident change is austenitic grain growth and tendency towards a transformation product more acicular in nature, as shown in Fig. 2.

A much more important point is concerned with the relative strength of these fully hardened structures at 1100 to 1400° F, and a series of stress-rupture tests established the data shown in the following tabulation:—

Stress Rupture at 1100° F

Time	N. at 1900° F	N. at 2100° F
10 hr	65,000 psi	80,000 psi
100	45,000	55,000
200	30,000	44,000

Stress Rupture at 1200° F

Time	N. at 1700° F	N. at 1900° F	N. at 2100° F
10 hr	23,000 psi	31,500 psi	38,000 psi
100	14,000	20,000	27,000
400		12,000	15,000

Stress Rupture at 1400° F

Time	N. at 1900° F	N. at 2100° F
4 hr	6500 psi	8300 psi
20	3400	4800

Thus, the special steel sheet normalised (air-cooled) from the highest temperature consistently has the best high-temperature strength at 1100 to 1400° F. Ductility (extension) at fracture was also higher for the samples heat-treated at the higher temperatures, despite the coarsened grain shown in Fig. 2. It was concluded that strengthening from increased amounts of foreign atoms dissolved in the ferrite more than compensates for the weakening effect of coarser grain.

To avoid decarburisation, the samples were heated in a hydrogen atmosphere. This high heat treatment at 2100° F (called Treatment A) would be a costly operation in commercial practice; hence, some of the 0·092-in. sheet was heated to 2100° F, air-cooled to 1850° F, and then reduced to 0·075 in. in one pass, and tested in creep immediately. This can be called Treatment B. (The previous stress-rupture results had been derived from 0·075-in. sheet rolled from 1850° F max.). The stresses for 1% creep and for rupture in periods varying from 10 to 200 hr were found to be of the same order for both Treatments A and B, with Treatment B having a definite advantage as testing times increased. Treatment B gave better ductility because of the resulting smaller grain size.

It would appear from these results that final reduction in hot rolling should be performed after heating to 2100° F. If any fabrication operation must be carried out at lower temperatures—such as ceramic coating—the stock should first be preheated to 2100° F and then cooled to the processing temperature, if maximum hot strength is required in service.

Fig. 3 has been produced by *Metal Progress* to present stress-rupture data in the form of a Larson-Miller "master curve"* for boron-treated Cr-Mo-Ti steel. This master curve enables reasonably accurate interpolation to be made. Thus, for example, if stress for a rupture time of 1000 hr at 1050° F is required, a vertical line from point *A* on the upper diagram down to point *B* on the master curve would indicate a stress of about 41,000 psi. For comparison, this figure shows a shaded band within which fall the master curves of a family of chromium, chromium-molybdenum, and molybdenum steels, ranging from 0·5 Cr-0·5 Mo at the lower end to 9·0 Cr-1·0 Mo at the upper. It is apparent that the boron-treated Cr-Mo-Ti steel under study is considerably superior to the Cr-Mo steels at low parameters—principally lower temperatures—but no better at temperatures around 1400° F. Even at 1200° F the creep-rupture strength drops sharply after 200 hr or more. These results suggest that the stiffening and strengthening effect of the supposed Ti-B-C precipitate tends to disappear with higher temperatures and longer times. Either the martensite tempers or the structure over-ages, depending on how the mechanism is regarded.

Welding

Some samples of 0·050-in. sheet, air-cooled from 2100° F, were welded by the "heliarc" method, with copper back-up strip to minimise the heat-affected zone. In one set the edges were flanged about 0·10 in. and the upstanding edges merely melted down. The bead or welt was then ground flush. Time at given stress for rupture at either 1100 or 1200° F was very considerably reduced; failure occurred at the edge of the weld metal and this situation persisted even when the welded sample was heat-treated.

Samples butt-welded with filler rod of Type 347 stainless steel gave similar results—except in certain

*F. R. Larson and J. Miller: "A Time-Temperature Relationship for Rupture and Creep Stresses," *ASME Transactions*, July 1952, p. 765.

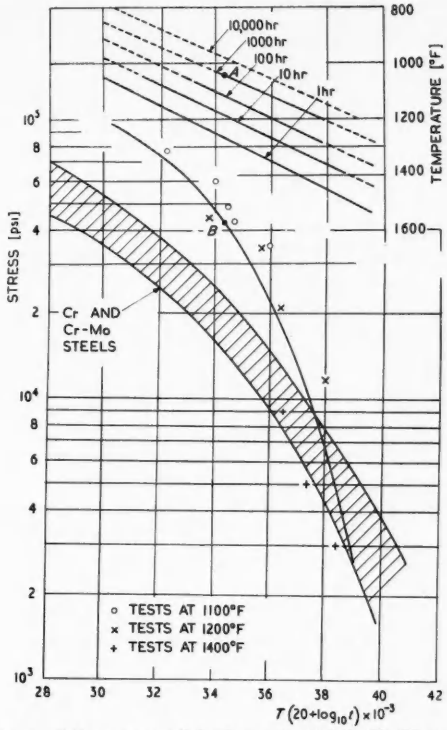

Fig. 3. **"Master curve" for boron-treated Cr-Mo-Ti steel, drawn according to the Larson-Miller scheme.**
T = °F + 460; t = rupture time [hr].

circumstances. If the bead was left on and the stresses were low enough to give rupture times of 150 hr or more, performance at 1200° F approached that of the parent stock.

Surface Protection and Carbon Content

A series of stress-rupture tests at 1200° F was made of metal from the 600-lb heat, wherein the samples were given optimum heat treatments (in hydrogen). Results showed a downward trend of stress with decreasing thickness. This could be due to decarburisation during rolling, heat treating, and testing, or to oxidation of the metal during testing.

It is evident that there is a composition and strength gradient from surface to centre of these samples, as is shown by the fact that, when 0·064-in. sheet is surface-ground on both sides to 0·050 in. and tested at 1200° F, it has strength significantly greater than that of the sheet rolled to 0·050 in., and, in fact, is about equal in strength to 0·081-in. sheet. These results indicated that surface scaling—at least, up to 400 hr—was not a factor.

Knoop microhardness tests across samples of 0·050-in. sheet and thicker showed hardness numbers of 375 at the centre and about 150 at the surface—again indicating decarburisation during rolling and hydrogen anneal, especially if the stock is slightly scaled. Thinner sheet (0·036 in.) was somewhat decarburised to the very centre, Knoop hardness there being only 250.

It is recommended, therefore, that thin sheet be descaled before the final 2100° F heat treatment. Otherwise, loss in carbon would lower the stress-rupture properties.

Decarburisation is undesirable from another standpoint, i.e., that even higher carbon than the 0·065% in the 600-lb heat would have been desirable. This is indicated by a series of tests at 1200° F on laboratory melts of boron-treated carbon-titanium steels, wherein the carbon and titanium contents were progressively increased, always staying within the ratio of 1·3 to 3·4. The results are shown in Fig. 4.

Conclusions

In the course of investigating the Ti-B type of ferritic steels for use as low-alloy materials in high-temperature service, several generalisations have evolved and these may be itemised as follows:—

(1) Compositions of the 3% Cr, 1% Mo, Ti-B type have displayed high-temperature creep and rupture-strength properties in sheet form, equivalent to those of the 18-8 Cr-Ni stainless steels at 1200° F for times up to 1000 hr.

(2) These maximum-strength properties are obtained with a Ti/C ratio of 2 to 4. Some precautions must be taken to hot-work the alloy below 1850° F, to prevent defects resulting from hot-shortness.

(3) It has been demonstrated that this steel ratio can be handled in a commercial mill.

(4) The high hot-strength properties may be obtained in heats up to at least 600 lb to the same extent as previously were characteristic of 30-lb laboratory melts.

(5) Heat treatment should be carried out in the range of 1900 to 2100° F. As the normalising temperature increases, better high-temperature properties result, because of the more complete solution of the titanium and boron, and of carbides of the alloying elements.

(6) Equivalent hot-strength properties with higher ductility may be obtained from hot-rolled sheet without subsequent normalising. If rolling is effected at 1850° F, the slab should be preheated to 2100° F and then processed after cooling to the rolling temperature.

(7) While some decline in creep and rupture strength may be obtained in light-gauge sheet, this can be avoided by protecting surfaces from decarburisation.

(8) High-temperature failure of heliarc-welded joints occurs within the fusion zone, both when no filler rod is used and when Type 347 stainless steel is used. Rupture strengths at 1200° F, equivalent to those of the parent metal, were not achieved, although close approach was made with the Type 347 filler-rod joint when the weld bead was not removed.

(9) The steel may be ceramic-coated satisfactorily, yielding high-temperature strength properties characteristic of the finishing temperature used in the processing. Such coatings are of value as a protection against air oxidation at temperatures near 1400° F, although they are of doubtful utility at 1200° F.

(10) Increasing quantities of carbon and titanium,

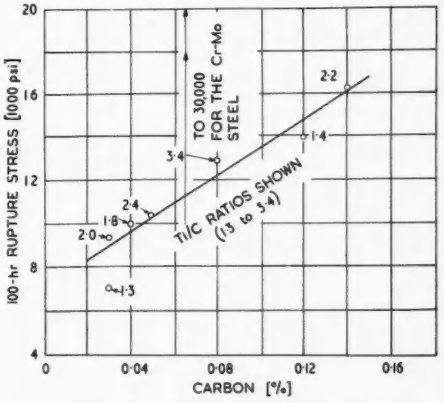

Fig. 4. **Effect of carbon content on rupture stress in 100 hr at 1200° F.**

with a constant Ti/C ratio of 3 to 6 in the C-Ti-B steels, and of 2 to 4 in the 3% Cr-1% Mo, Ti-B grade, improve the high-temperature properties up to carbon contents of 0·15 to 0·20%, the maximum quantities investigated.

(11) Boron, varying from 0·10 to 0·010%, causes negligible change in the creep properties of C-Ti-B steels, in spite of a eutectic network appearing in the higher boron steels.

(12) Molybdenum was very effective in improving the hot-strength properties of the plain C-Ti-B steel; 1% Mo doubles the 1200° F rupture strength for 100 hr.

(13) The phenomenal high-temperature strength of the Ti-B steels is related to their ability to form a hardened, low-temperature transformation product of acicular ferrite, remarkably resistant to tempering. This is the result of solid solution hardening and diffusion interference effects of both boron and titanium, the retention of some carbon and titanium in the supersaturated ferrite, and the dispersion hardening effect of the precipitated titanium carbide.

U. S. A.

The Place of Oilless Bearings in Industry

By C. D. SPADONE. (From *Iron and Steel Engineer*, Vol. 31, No. 9, September 1954, pp. 185-191, 5 illustrations.)

ALTHOUGH comparatively little has been written on the subject, it would be difficult to find an industry to-day which does not make effective use of oilless bearings in some application. The tremendous increase in production during the last decade has demanded higher operating efficiency, and oilless bearings have continued to meet the greater temperature, load, and speed requirements.

The term "oilless" should not be confused with "self-lubricating" for, as the name implies, oil or grease is not contained in the bearing itself nor is it necessary to add these or other lubricants. This distinction makes it readily apparent that oilless bearings will normally function in higher temperatures than self-lubricating types, which tend to exhaust their lubricant under heat conditions.

This study essentially concerns oilless bearings having a dry metallic lubricant, but it is also important to consider other main types in this bearing classification. For the sake of discussion, these are broken down into four groups:—

(1) Composition metal bearings containing lubricant in the mixture.
(2) Composition plastic and rubber bearings containing lubricant in the mixture.
(3) Carbon graphite bearings.
(4) Solid metal bearings drilled or grooved to hold the lubricant.

Composition metal bearings usually consist of bronze or iron powders mixed with graphite. The mixture is then compressed into form under high unit pressure, sintered for strength and hardness, and may or may not be subjected to final machining, depending on the method of manufacture and required tolerances. Composition oilless bearings are similar to self-lubricating oil-impregnated bearings in porosity but, as graphite is inert, they tend to be somewhat brittle. However, under moderate conditions of load, speed, and temperature, they give efficient service.

Bearings of this type are also made in several other ways. One method is to machine a solid graphite bar to dimensions, after which it is immersed in molten bronze or other alloy. The metallised graphite is then placed under pressure for final form and finish. Another process is to press a mixture of graphite and metal powders into block or core form. The piece is then machined to final dimensions. Suitable for light duty at higher speeds, these bearings are recommended for loads up to about 50 pounds per square inch of projected bearing area, and for temperatures of approximately 200 to 300° F.

Composition plastic bearings consist of plastic compounds often mixed with a percentage of graphite, and are effective when used under abrasive conditions. Having less wear resistance than metal, the abrasive wears the bearing rather than the shaft.

Plastic bearings have low heat conductivity, and temperatures should be kept within 200° F. The type most widely used in the steel industry is roll-neck bearings, and these are most efficient when water is used as a lubricant. However, for general use, if loads and speeds are moderate, the impregnated graphite lubricant is usually sufficient.

Carbon graphite bearings consist of a mixture of carbon and graphite powders compressed to shape and finished to final dimensions. Certain sizes accept a minimum tolerance of 0·010 in., and, where smoothness is required, polishing may be employed. Porosity varies with the grade of carbon graphite used, and some will not absorb any fluid, while others may absorb up to 20% by volume. The expansion and contraction of this material are about the same as those of metal, which is therefore frequently used as a backing to impart strength for heavy-load or high-temperature applications. These bearings can be run dry or lubricated with light fluids, as desired, and 100 psi at 300 fpm and 250° F is representative of the operating range. Coefficient of friction ranges from 0·04 to 0·25, depending on the grade used.

Solid metal bearings, drilled or grooved to hold the lubricant, comprise the fourth group, which consists of two main types, *i.e.*, bearings lubricated with graphite paste wiped under pressure into recesses, holes, or grooves and then heat-treated to form a compact mass; and bearings lubricated with pre-moulded metallic plugs inserted in the bearing wall.

The metallic plug-type bearings are similar in appearance to those lubricated by graphite only, but they have a wider range of application and provide longer service under heavier load and higher temperature conditions. In normal use, the metallic lubricant will last the life of the bearing.

These bearings, a typical example of which is illustrated in Fig. 1, are made of cast bronze, cast iron, or other metals, depending on requirements. They are usually not a stock item but made to order, and can be furnished in an unlimited variety of sizes and shapes, as shown in Fig. 2. They are therefore of particular interest to the machine designer and maintenance engineer.

Before further consideration of oilless bearings in the finished form, it may be helpful to give some thought to various dry or solid lubricants which bear out the theory of solid lubrication. It is commonly accepted that the two main types of friction created in mechanical actions are either solid or fluid, and the effect of solid lubrication on solid friction has been clearly described by Thomsen*, who states that, when solid lubricants are introduced between unlubricated surfaces, they act as smoothing agents, filling pores and imperfections in the metal surfaces, and coat the surfaces with a thin layer of solid lubrication. Solid lubricants have little cohesion and, therefore, when abrasion takes place, it is between

*"The Practice of Lubrication," 1951.

particles of the solid lubricant rather than the original surfaces. By use of a solid lubricant, the solid friction of the original surfaces is actually replaced by a lesser solid friction between the lubricants. Thus, when solid lubricants are used, abrasion and cutting of the original metal surfaces is less likely to occur. Thomsen adds that addition of a solid lubricant to a fluid lubricant in a perfectly lubricated installation did not interfere with performance. Moreover, it was found that, although friction increased immediately after adding the solid lubricant, as soon as it had time to adhere to the surfaces friction was reduced.

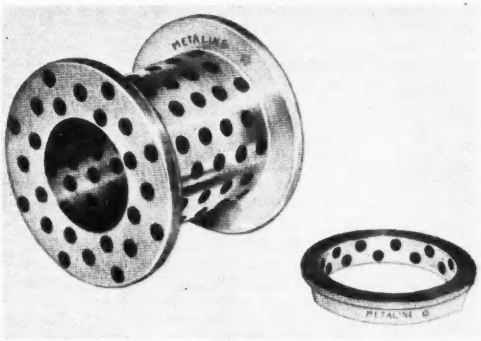

Fig. 1.

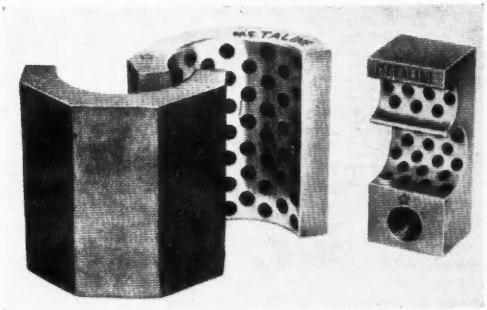

Fig. 2.

One of the many virtues of solid lubricants lies in their effect on the rubbing surfaces at the moment of starting. As the lubricant coats or films the original surfaces and as this film will stand up under stationary load and will resist squeezing out, there is a resultant reduction in the static coefficient of friction at the moment of starting. It is generally agreed that the use of dissimilar metals for the rubbing surfaces is desirable from both a friction and seizure standpoint. Cast iron and hardened steels may be exceptions to this rule, but even they should not be used for both members when bearing pressures are high. Solid lubricants in the pure state with above-average film-forming characteristics are graphite and molybdenum disulphide. Both have laminar structures, perform well under heavy load, and maintain low coefficients of friction at high temperatures. Now produced in a highly pure form, MoS_2 has proved efficient and in many cases superior to graphite. It tends towards a lower friction value than graphite, particularly at higher sliding velocities, has excellent film-producing properties, and has above-standard resistance to pushing or squeezing out. It is, however, still too new to permit many set or far-reaching conclusions, and there is some difference of opinion on its effectiveness under actual operating conditions. Nevertheless, it appears to be a most promising member of the dry-lubricant family and, with the development of better mixtures and means of application, it is hoped that further improvements in the operation of oilless bearings can be effected.

Boyd and Robertson have shown molybdenum disulphide, graphite, and tungsten disulphide to have the most stable and lowest average coefficients of friction of various lubricants tested. Two of these lubricants had an average coefficient of friction of 0·032, while graphite had 0·036. In comparison, machine oil, which was one of many other lubricants tested, had an average rating of 0·099. These figures serve to illustrate the very definite place and value of oilless lubricants in the lubrication field.

Advantages of dry or solid lubricants include the following:—

(1) They reduce solid friction.
(2) They fill pores and irregularities in metals and provide a highly polished surface film capable of withstanding heavy loads and resistant to scoring or abrasive action.
(3) They do not require maintenance and are ideal for inaccessible locations.
(4) They greatly reduce consumption of lubricant.
(5) They substantially reduce maintenance cost.
(6) They assure dependable lubrication under high temperatures.
(7) They exhibit a high degree of resistance to squeezing out and maintain maximum lubrication under static load. The coefficient of friction at the time of starting is therefore relatively low.
(8) They are clean and eliminate the risk of fire from oil or grease drippings.

In recent years it has been recognised that certain properties should be considered in determining the advantages or limitations of a bearing for a particular application. These properties were originally set forth as pertaining only to the metal or alloy, but have proved helpful in describing various properties of oilless bearings. Bearings intended for oilless operation should have better than average rating in most of these classifications.

Classification of Properties

Conformability:—This is the ability of the bearing to conform to surface irregularities of the shaft, thus affording more uniform distribution of the load. Plasticity is inherent in this characteristic and if, for instance, the pre-moulded plug-type bearing is compared with a babbitt bearing, a low degree of conformability would have to be assigned to the former. On the other hand, when compared with a plain sleeve bearing, its rating would be high. The pre-moulded plugs, composed of metallic oxides and other soft ingredients, expand under frictional or induced heat at a higher rate than the metal in the bearing wall. As the plugs expand, a film is quickly built up on the moving surfaces. This expansion and the resultant film thickness vary with the pressure points within the clearance and tend to distribute the load evenly.

Non-scoring characteristics:—Possibility of scoring is usually most prevalent during the starting-up period or when the range of critical operation has been reached. Oilless bearings, particularly those in the metallic lubricant group, rate highly in this respect. The polished, hard protective film safeguards the journal under both static and running load. When run within the recommended operating range, scoring should never be a problem.

Compressive strength:—This is the ability of the metal bearing wall to withstand load and shock without distortion or breaking. Taking the solid bronze plug or grooved bearing as an example, it is found that the bronze most generally used for normal application has a compressive rating of 14,000 to 16,000 psi. In terms of load, capacities range from 1000 lb per sq in. of projected

bearing area up to 4000 for aluminium bronze. Depending on requirements, materials other than bronze may be used, but, in any event, this type of bearing is considered to have a most satisfactory compressive rating.

Fatigue resistance:—The fatigue resistance of bronze, cast iron, and similar metals is high enough to cause little concern, but it is important when considering white metal, aluminium, or copper alloys. However, it is seldom necessary to emphasise this factor when determining the suitability of solid metal oilless bearings for an installation.

Embeddability:—This is the ability of a bearing to permit dirt or foreign matter to embed in its surface, thereby minimising abrasive action and scoring of the shaft. Oilless bearings rank high in this respect, as any grit is quickly driven into the holes containing the softer lubricant. Pressure tends to hold the dirt particles in the recess and away from contact with wearing surfaces. Naturally, if grit conditions are excessive, the life of the bearing will be shortened, for the grit will displace and force out an equivalent amount of lubricant. However, in such instances it is usually practicable and less expensive to sacrifice the bearing rather than to risk damage to the shaft or equipment.

Corrosion resistance:—Oilless bearings are often chosen on the basis of corrosion resistance alone. Being oilless, these bearings automatically avoid the problems of oil oxidation at high temperatures and resultant organic acid. In addition, they are widely used in underwater installations, and will serve in surroundings where chemicals in the atmosphere would affect other lubricants.

Clearances:—The subject of clearances is most important in considering the success or failure of any bearing application. This clearance accommodates the metallic film or lubricant, which prevents metal-to-metal contact of the moving surfaces. It is impossible to set hard and fast rules for all applications, and clearance data are usually based on a study of the factors involved in a given operation.

Standard clearances, as set forth by the manufacturer, can of course be relied upon under normal conditions, but when seeking information it should be remembered that load, speed, temperature, shaft size, and type of bearing required are highly important factors.

Pre-moulded metallic plug bearings permit generous clearance, as there must be room for the plugs to expand and build up a protective coating on the shaft and bearing wall. Clearances vary with the size of the bearing and operating conditions. They may range from 0·003 in. for smaller bearings at normal temperature, up to 0·042 in. for larger bearings at 800° F. When compared with oil-lubricated bearings, this may seem excessive, but when the film-building properties and expansion of the lubricant are taken into consideration, it can be seen that the final operating result is a normal running fit between journal and bearing.

Proper installation is another factor directly related to both clearance and operational efficiency. Improper alignment or fit are obvious trouble-makers, but often overlooked are the thermal expansion properties, which may differ for the metals employed. Uneven wear, distortion, or seizure may result, and the bearing may be blamed for failure which was actually the fault of improper installation.

Practical Engineering Data

Load capacities:—A conservative load rating per square inch of projected bearing area is 1000 lb. Loads of 4000 lb per sq in. of projected bearing area are also permissible, depending on the metal alloy used. As a general rule, bronze oilless bearings will withstand the same pressures as comparable oil-lubricated bronze bearings.

Temperature:—These bearings are recommended for temperatures up to 750° F, but this is commonly exceeded. For instance, there are known applications where bearings have given 24-hr service at 800° F over many years. These oilless bearings are also widely used in oven cars, which are often subjected to temperatures over 1000 F, and their efficiency and service are known to be satisfactory. However, caution and commonsense should be exercised when operating recommendations are exceeded. A good rule to follow is that when one of the factors of load, speed, or temperature is excessive, the others should be reasonable.

Speeds:—Recommended speeds for oilless bearings are given in surface feet per minute and over 500 fpm is considered critical. As surface speed is affected by shaft size, there is naturally considerable variance in terms of rpm.

Wall thickness:—Plugged or grooved bearings should have a wall thickness heavy enough to permit proper introduction of the lubricant. Wall dimensions range upward from $\frac{3}{16}$ in. for smaller bearings, to $\frac{7}{16}$ in. for larger bearings and, although these represent normal recommendations, they are subject to change if special conditions warrant it.

Bearing length:—Optimum length should be $1\frac{1}{2}$ times the inside diameter. However, in actual practice this rule is often deviated from; thus, for instance, sheave bearings are generally made with length about equal to diameter. When necessary to design a bearing for heavy loads, it is suggested that, whenever possible, the length be increased rather than the diameter.

Coefficient of friction:—This will vary with the application and, because of the many variable conditions, specific information is not always available. It is unfortunate, but because frictional tests are conducted under controlled conditions, results are usually given in indicative rather than conclusive terms. The frictional coefficient of metallic lubricated bearings is similar to that of graphite and ranges from 0·04 under heavy load, to 0·17 under light load.

These specifications are determined from practical experience and allow for other variable factors, difficult to predict, but nevertheless affecting bearing operation. Machine vibration, shaft distortion, improper installation, and excessive abrasion cannot be anticipated and, although manufacturers' recommendations include some margin of safety if the application is critical, actual trial of the bearing is the only dependable way of knowing what performance may be expected. This is best illustrated by a test made to determine the maximum load capacity of a two-piece metallic plug bearing, 2-in. i.d. × $2\frac{3}{4}$-in. o.d. × $1\frac{1}{2}$ in. in length. At 34 rpm and with a load on the projected bearing area of 1867 psi, the bearing was slightly warm; at 34 rpm and 4000 psi, the bearing became warmer, but was not too hot to hold in the hand; at 36 rpm and 5000 psi, the bearing was too hot to hold, but was undamaged, running free; at 36 rpm and 8000 psi, it was hot, running free; and at 38 rpm and 8000 psi, it was smoking, though uninjured, running free. Thus, performance exceeded the normal recommendation, in this instance.

Manufacturers are continually striving to meet new conditions and it is recognised that there is still room for improvement in present bearings. Extensive research and laboratory tests are now being carried out and it is hoped the results of this work will open the door to broader use and application of oilless bearings.

What the future holds is impossible to predict, but the place of oilless bearings in meeting the needs of industry is well established and, although they are not represented as a "cure-all," industry can look to the oilless bearing as a probable solution, when cleanliness is important, when maintenance is difficult, when high temperatures must be met, or when special design is essential.

The Combustion of Single Droplets of Fuel

By K. KOBAYASI. (From *The Technology Reports of the Tôhoku University*, Vol. 18, No. 2, 1954, pp. 223-234, 17 illustrations.)

*The work described in this article is an attempt to study the combustion process of single droplets of fuel by means of motion-picture recordings, using experimental apparatus and procedure very similar to those used in a previous study of the evaporation velocity of single droplets of liquids.**

THE apparatus used to investigate the combustion of single droplets of fuel was similar to that employed in the author's previous study of the evaporation velocity of single droplets of liquids, in which an electric furnace on rails can be pushed into position to cover entirely the droplet, which is suspended from a quartz fibre, the behaviour of the droplet being recorded by a 16-mm motion-picture camera and a suitable illuminating and optical system.*

The results of these combustion experiments are as follows :—

PURE LIQUID FUELS

With increasing temperature of the surrounding air, the evaporation of a fuel droplet becomes more intense and finally it burns by self-ignition. An example of such a procedure is shown in Fig. 1, as measured from shadowgraphic motion pictures. The relation between the diameter D of a droplet and the time t during combustion under constant air temperature is represented by

$$\frac{d D^2}{d t} = \text{constant} = -C_b \qquad (1)$$

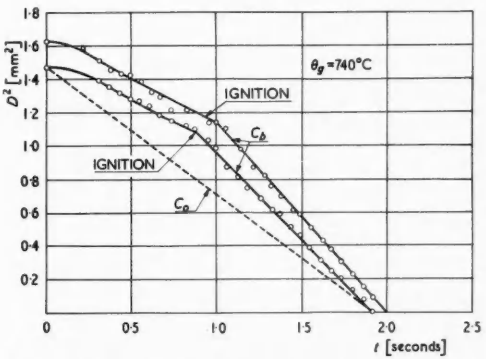

Fig. 1. **Ignition and combustion of a droplet of benzene, with coefficients C_b and C_o of true and apparent combustion velocity respectively.**

This is similar to the case of evaporation, with the exception that the slope of the straight line after ignition is greater than it is in evaporation. This means that, in the case of a volatile fuel, the phenomenon of evaporation predominates at the surface of the droplet even during combustion, and the layer of the flame of combustion, in which the vapour diffuses outwards, exists at a distance where the vapour is mixed in a suitable ratio with air.

It may be convenient to represent the rate of combustion velocity of the droplet by the slope C_b of the straight-line portion, which may be called the "coefficient of true combustion velocity," similar to that in the case of evaporation of the droplet. Furthermore, the following relation exists :—

$$\frac{\tau_o}{D_o^2} = \text{constant} = \frac{1}{C_o} \qquad (2)$$

where the initial diameter of the droplet is D_o and the life of the droplet is τ_o. The ignition lag, as shown in Fig. 1, decreases with the increase of the air temperature θ_g, but it always accompanies the fuel droplets injected into high-temperature air. Therefore, the life

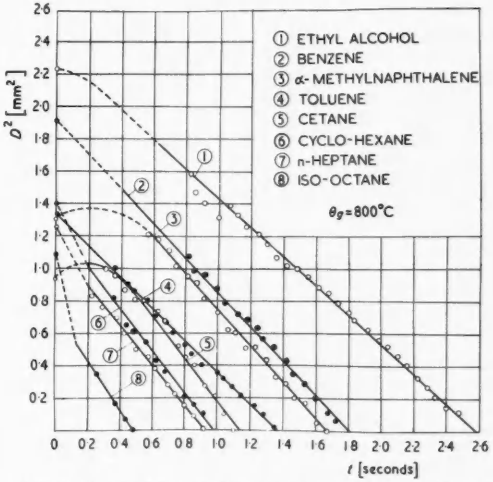

Fig. 2. **Combustion of droplets of various types of pure fuels.**

of the droplet, necessary in practical cases, may be found briefly by using C_o, which may be called the "coefficient of apparent combustion velocity." If the ignition lag is negligibly small, as in the case of a volatile fuel droplet with a low boiling point, injected into air of sufficiently high temperature, C_o becomes nearly equal to C_b. The combustion processes of droplets of various types of pure fuels in air of temperature $\theta_g = 800°$ C are shown in Fig. 2, in which it can be seen that the relation of eq. (1) is satisfied.

MECHANISM OF IGNITION OF FUEL DROPLETS

The process of ignition of droplets of benzene, photographed at 64 frames per second, clearly shows the details of a transient state from ignition to steady combustion. At first, one part of the mixture, with a suitable air/fuel ratio among the layers of co-spherical mixtures around the droplet, is ignited; next, the flame propagates circumferentially and then, inside the diffusion zone, almost uniformly. The mixtures inside the diffusion zone are so rich that at the next moment, in the case of fuels with larger carbon contents, the carbon particles are produced uniformly by vapour-phase cracking in that zone, while natural convection does not yet occur. Then, after the beginning of natural convection, as a result of the heat released, the combustion products are moved upwards with partial burning by fresh air supplied from below, until steady combustion sets in. Behaviour similar to that of benzene droplets was observed in the ignition of toluene, nitrobenzene, α-methylnaphthalene, light diesel oil, kerosene, and heavy oil. The rate of decrease in diameter of the droplet in such a transient state of ignition is not very high.

PETROLEUM FUELS

Motor gasoline burns similarly to pure fuels, as

* *The Engineers' Digest*, November 1954, pp. 463-465.

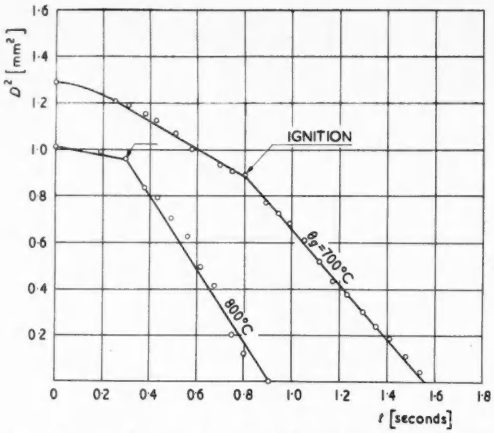

Fig. 3. **Combustion of a droplet of motor gasoline (S.G. = 0·742).**

shown in Fig. 3, in which it can be seen that evaporation is the governing factor. However, light oil burns in a different manner, as shown in Fig. 4, in which the following facts can be observed :—While the air temperature is lower, the relation between the square of the diameter of the burning droplet and time is represented by a straight line, as in the previous case; however, in the evaporation and the heating period before ignition, the droplet increases and decreases in size as a result of the superposition of thermal expansion, evaporation, and peroxidation, and when the droplet becomes smaller in the vicinity of the final point, its diameter shrinks at a higher rate by liquid-phase cracking, as a result of overheating due to thermal conduction from the quartz fibre. If the quartz fibre were absent, the droplet might burn along the dotted line in the figure. This means that the temperature of these burning droplets is near the cracking temperature. Thus, when the air temperature rises, the straight-line relation is upset.

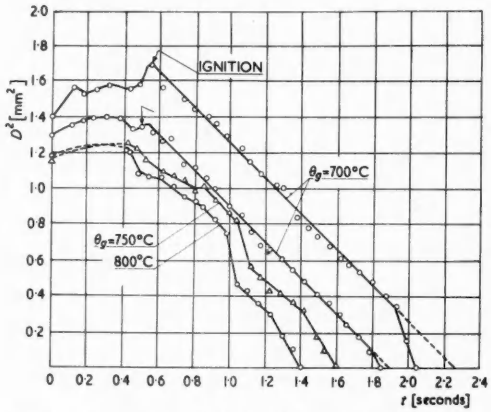

Fig. 4. **Combustion of a droplet of light diesel oil. (S.G. = 0·828).**

Heavy oil is more remarkable in this respect. After the evaporation of the lighter constituents, the heating of the remainder produces a very viscous semi-solid residue. Accordingly, the bursting of vapour bubbles produced by internal vaporisation and internal liquid-phase cracking in the droplet produces splashes of viscous residue which burn when passing through the flame layer, and these splashes throw out secondary splashes, similar to the sparks produced during the grinding of carbon steel. For such combustion, the change in diameter of the droplet is complex, as shown in Fig. 5, in which the peaks and the troughs indicate the conditions of the droplet with fully expanded internal bubbles and after the scatter of splashes, respectively. A characteristic behaviour during the combustion of a heavy oil droplet is that the droplet vanishes suddenly after a final expansion, as shown in Fig. 5.

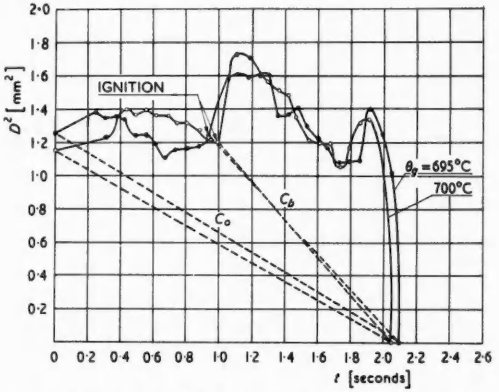

Fig. 5. **Combustion of a droplet of heavy oil. (S.G. = 0·918).**

The heavier the fuel the larger is the rate of peroxidation ; it may therefore be imagined that it is this peroxidation in the droplet and inner combustion which produce the frothing and the scatter in heavy oil. Motion pictures, however, establish that frothing and scatter during the combustion of a heavy oil droplet are almost entirely caused by the vapour produced by thermal cracking, and little by peroxidation and inner combustion.

As the relation of eq. (2) is satisfied, even in such complex combustion as that of both light and heavy oil, the coefficient of combustion velocity may be found as the mean value of C_b and C_o.

Coefficients of Combustion Velocity for Various Types of Fuels

The coefficients of true and apparent combustion velocity have been measured* by means of motion pictures for various kinds of fuels, and, if the initial diameter of the droplet is given, its life may be found by using these coefficients. From these measurements, if has been shown that the temperature θ_g of the surrounding air has not so much influence on combustion as it has on evaporation, because the flame temperature directly affects the combustion velocity.

* Measured values of these coefficients are tabulated for 15 fuels in the original article.—Ed., E.D.

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Radiographic Properties of X-Rays in the Range between Two and Six Megavolts

By C. H. Goldie, K. A. Wright, J. H. Anson, R. W. Claud, and J. G. Trump. (From *ASTM Bulletin*, No. 201, October 1954, pp. 49-54, 9 illustrations.)

The dominant absorption mechanism in the lower million-volt X-ray range by which photons are diminished in energy and scattered is the Compton effect. In these interactions, dependent primarily on electron density, the photon collides with and imparts energy to an atomic electron, and then proceeds in an altered direction with correspondingly diminished energy. These modified photons are the principal source of scattered radiation.

In this energy range the pair-production mechanism of X-ray absorption in steel is a lesser factor. In this process the photon energy is converted into the rest mass of two electrons which carry away the remainder of the incident photon energy. Pair-production first appears at 1·02-million volts, the rest energy of two electrons, and thereafter increases with photon energy and the atomic number of the absorber. For 6-million-volt photons, for example, pair-production process in iron causes about half as much absorption as the Compton process, while in lead pair-production absorption is about 50% greater than Compton absorption for this energy[1]. The positive electron produced in this process disappears at the end of its path by combining with an atomic electron somewhere in the absorber, usually with the emission of two photons of 0·5-million volts energy. This annihilation radiation is another source of scattered radiation in the high-energy region.

The photoelectric process, which is the principal absorption mechanism for X-rays below 100 kV, particularly with heavy metals, is negligible in the million-volt region.

The direct, or picture-bearing, radiation emerging from an absorber is that portion of the incident radiation still travelling in the original direction. It is the radiation which would emerge if all interactions were complete absorption processes. Unfortunately, the scattered radiation produced within the absorber contributes greatly to the emerging radiation, but serves only to fog the film. The total transmitted beam is the sum of this direct and scattered radiation.

A monochromatic direct X-ray beam would be attenuated in an absorber according to the relation

$$I = I_o \epsilon^{-\mu x} \quad .. \quad .. \quad .. \quad (1)$$

where I = the intensity at depth x in the absorber, I_o = the incident intensity, and μ = the linear absorption coefficient. The logarithm of the monochromatic direct-beam intensity plotted against absorber thickness is a straight line of slope μ.

The continuous radiation spectrum from an X-ray target contains photons of all energies up to the maximum tube voltage. Since the linear absorption coefficient μ diminishes steadily with increasing photon energy (until about 7-million volts for iron), the selective absorption of the less energetic photons shifts the spectrum of the direct radiation toward the short wavelength limits. This shift toward the high-energy end of the spectrum soon becomes extremely slow; the direct-beam transmission curve plotted as in Fig. 1 becomes almost a straight line, and the beam behaves as essentially monochromatic radiation. Thus, any direct X-ray beam, after sufficient initial absorption, can be described by an effective absorption coefficient, μ_D. The value of μ_D is usually obtained from direct-beam curves which extend down to about 0·1% of the incident intensity. It is technically impossible to carry the direct-beam transmission measurements far enough to reach the absorption coefficient of the highest-energy radiation in the beam.

Total-beam transmission curves are quite different in appearance. The total radiation includes both the direct-beam and the scattered radiation, which increases rapidly in the first small absorber thicknesses. As seen in Fig. 2, this semilog curve becomes progressively steeper until a few inches of steel have been traversed, after which it becomes virtually straight.

Feshbach[2] has suggested that this straight semilog plot indicates that an equilibrium is reached between the higher-energy components of the transmitted beam and their accompanying scattered secondaries, after which the total beam behaves as if it were a monochromatic beam with an energy equal to the highest energy in the continuous spectrum. It should be noted that, at infinite thickness of absorber, both the direct- and total-radiation curves should have the same slope.

Within the range of thickness for which accurate detection of the radiation can be accomplished, it has been found experimentally for 1- and 2-million-volt X-rays that the ratio of the scattered to the direct radiation is proportional to the thickness of the absorber[3].

Experimental Apparatus and Procedure

The X-rays from two Van de Graaff accelerators used, one a Massachusetts of Technology (MIT) generator of 3-million volts, and the other an Office of Naval Research (ONR) generator covering the 4- to 6-million-volt range, had an equivalent filtration of about 11 mm of lead, most of which was in the ¼-in.-thick gold targets. With the ONR generator, working space was gained by magnetically deflecting the electron beam through 90 deg. before allowing it to strike the target. The MIT generator was calibrated for negative operation, and the two lower voltages, which were obtained with this machine, are known to an accuracy of better than ±3%. Although the ONR machine was very accurately calibrated for positive ion operation, estimated accuracy for its operation as an X-ray source for the 5- and 6-million-volt data is ±5%.

The X-ray energy incident on the absorber was monitored with a thin-wall flat ionisation chamber placed in the field close to the X-ray target and connected to a remote modified Shepard-Roberts d.c. amplifier. A special flat ionisation chamber with adjacent pre-amplifier and remote amplifier and indicating circuit was used to measure the transmitted intensity. This detector was shaped to approximate the conditions of actual radiography, the mean depth of its thin, flat air cavity being about the same distance beneath the bottom of the steel plates as a film in a pressure cassette.

For the direct-beam measurements, the detector was placed remote from the steel absorber and surrounded with a lead shield, 3 in. in thickness, to reduce approaching scattered radiation. The 2- and 3-million-volt transmission curves were obtained with fields defined to 4 by 4, 10 by 10, and 25 by 25 cm at the detector, with set-up dimensions as indicated in Fig. 3, which also shows the 3-megavolt curves. The small difference between the transmission of the two smaller fields suggests that the 4 by 4-cm data can be accepted as the direct-beam curve with only small error. Because of the poorer electron-beam focus in the ONR accelerator, the field size used for the direct-beam measurements at 5- and 6-million volts was increased to 6 by 6 cm, the target-to-detector distance increased from 100 to 135 cm, and the distance from absorber to detector from 39 to 62 cm. Under these conditions the detector chamber had a somewhat smaller solid angle for scatter from the steel plates.

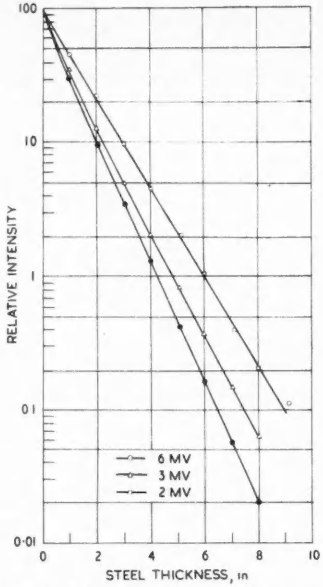

Fig. 1. **Direct-beam transmission curves in steel for 2-, 3-, and 6-megavolt X-rays**

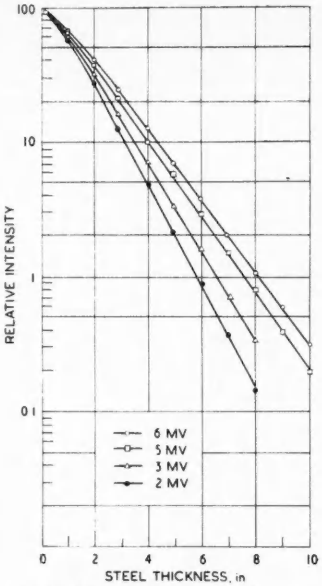

Fig. 2. **Total-beam transmission curves in steel for 2-, 3-, 5-, and 6-megavolt X-rays, with a 25 × 25-cm field.**

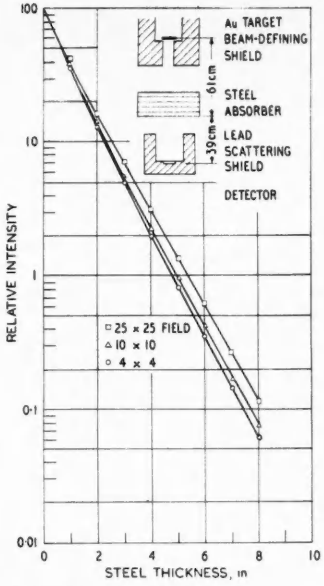

Fig. 3. **3-megavolt transmission curves in steel for different field sizes with direct-beam set-up.**

The total-beam data were taken for three fields for the two lower voltages and for two fields for the higher voltages. In these measurements the target-to-detector distance remained the same as in the case of the direct-beam set-up, but the steel was stacked directly against the lead block containing the detector. This lead block provided protection from general room scatter.

Results of Direct- and Total-Beam Measurements

Fig. 1 shows direct radiation as a function of steel thickness for 2-million, 3-million, and 6-million-volt X-rays. The focus of the electron beam in the ONR machine had been adjusted for 6-million-volt operation and was left unadjusted at 5-million volts, with resultant defocusing and error in the 5-million-volt direct-beam data. Unavailability of the ONR machine prevents the repetition of this run. The direct-beam curves are sufficiently straight to permit the calculation of an absorption coefficient and an "equivalent energy."

Fig. 4 shows total transmitted radiation as a function of thickness for 4 by 4, 10 by 10, and 25 by 25-cm fields of 3-million volt X-rays, while Fig. 2 shows the total transmitted radiation for the 25 by 25-cm field with 2-, 3-, 5-, and 6-million-volt X-rays. The plots are essentially straight lines on the semilog paper. These two figures demonstrate the considerable dependence of total transmitted radiation on both field size and voltage.

X-ray Intensity and Exposure Time

Since most radiography is carried out with fields at least as large as 25 by 25 cm, this field size and a commonly used high-quality film, Eastman Type A industrial radiographic film, were chosen for the calculation of an exposure chart. This film requires a radiation dose of 4 roentgens to produce a film density of 3. This dose is practically independent of radiation energy above about 300 keV.[4] A density of 3 was selected, because a chart constructed for this density, combined with the latitude curves, makes it simple to determine the maximum thickness that can be radiographed at a given tube voltage with a 1% sensitivity.

The zero-thickness exposure points on the chart require a knowledge of the output intensity at each voltage. A plot of output X-ray intensity in roentgens per μA-min at 1 metre, as measured on the 3-million-volt X-ray generator, shows that the output intensity is proportional to $V^{3.4}$, where V is the voltage in the range from 1-million to 3-million volts. Although absolute measurements of the X-ray output could not be made on the ONR machine because of the lack of knowledge of the actual target current, relative measurements indicated that the $V^{3.4}$ rule held to the highest voltage. Therefore, the zero-thickness points for the two higher voltages were taken from an extrapolation of the curve. From zero thickness up, the exposure curves for 2-, 3-, 5-, and 6-megavolt X-rays are the inverse of the 25 by 25-cm total-beam transmission plots. If a lower density or a different film is preferred, correct exposures can be computed by multiplying the value given on the chart by a constant factor obtained from film-response curves. It should be noted that the exposure curves will apply accurately only with lead intensifying screens of sufficient thickness to produce electron equilibrium with the X-ray radiation.

Scattering Factor

Calculations of radiographic sensitivity for the various voltages first require determination of the scattering factors κ. The scattered radiation was found by subtracting the direct from the total radiation for each thickness. The ratio of the scattered to the direct radiation was then plotted against steel thickness for each voltage; the resultant curves are approximately linear, and the values of κ/μ, a factor often used as an index of radiographic merit, were found to be 0·93, 0·75, and 0·67 for 2-, 3-, and 6-megavolts tube voltage respectivelv, with total-beam absorption coefficients μ [in.$^{-1}$] of 0·86, 0·75, and 0·61.

Radiographic Sensitivity

Since sensitivity is the minimum observable thickness variation expressed as a percentage of the total

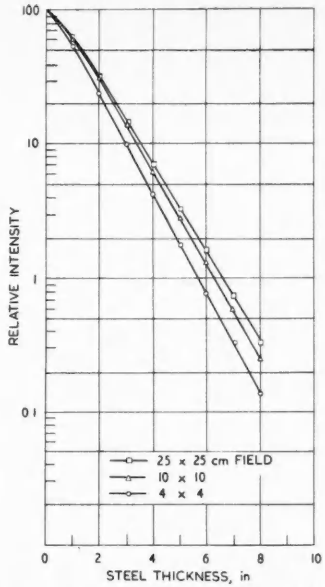

Fig. 4. **3-megavolt total X-ray transmission curves in steel for different field sizes.**

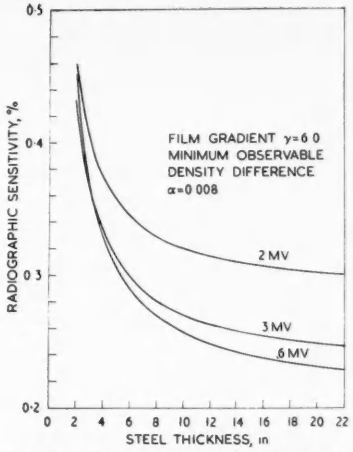

Fig. 5. **Sensitivity against steel thickness for 2-, 3-, and 6-megavolt X-rays, with a 25 × 25-cm field.**

thickness of the absorber, it is desirable to have a low sensitivity. Scattered radiation plays its major rôle in adversely affecting sensitivity. Without scatter, the radiation intensity on a film under an examined object would depend at each point only on the thickness x of metal directly above that point. In this idealised situation the sensitivity would be

$$S = 2{\cdot}3\alpha/\gamma\mu x \quad .. \quad .. \quad .. \quad (2)$$

where α = the minimum observable film density difference, usually taken to be 0·008, and γ = the film gamma or slope of the curve of film density *versus* $\log_{10}$ relative exposure.

Eq. (2) indicates that low-voltage X-rays, with their correspondingly higher absorption coefficients, would give the best sensitivities. However, scatter cannot be eliminated in practice. Placing the film remote from the absorber or using a moving grid between the absorber and film to block out oblique radiation greatly reduces the scatter to the film but causes a loss of definition and increased exposure and set-up time.

The expression for sensitivity, including the effect of scattered radiation[5], is

$$S = \frac{2{\cdot}3\alpha}{\gamma\mu x}(1 + kx) = \frac{2{\cdot}3\alpha}{\gamma\mu x}\left(\frac{T}{D}\right) \quad .. \quad (3)$$

where D = the direct radiation, and T = the total radiation at depth x.

Thus, sensitivity with scatter is equal to sensitivity without scatter multiplied by the ratio of the total to the direct radiation. If the direct beam could be used free of scatter, the detectable thickness difference would be constant and would depend only on the film contrast and the absorption coefficient. This condition of "absolute sensitivity" is approximately realised for thin sections, using extremely high-voltage X-rays.

With large thicknesses, the sensitivity with scatter approaches the constant value.

$$S_\infty = 2{\cdot}3\ \alpha\kappa/\gamma\mu \quad .. \quad .. \quad (4)$$

Qualitatively, κ/μ increases with voltage to a maximum at about 0·5-million volts, after which it decreases rapidly at first and then more slowly. Thus, sensitivity actually improves with increasing voltage above 0·5 million volts, and is still improving slowly in the 2- to 6-megavolt region.

Use of the experimental values for the scattering factors in eq. (3) for sensitivity results in the curves shown in Fig. 5. These curves were calculated on the basis of a film gamma of 6 and α of 0·008. It is clearly shown that the sensitivity for sections thicker than 4 in. is better for 6- than for 3-million volts. However, this gain is small compared with that obtained in changing from 0·5-million volts to 2-million volts, or even from 2- to 3-million volts.

The sensitivities discussed above are for the ideal case of flat plates. Actual objects to be radiographed vary in shape, and the calculation of sensitivity can be extremely involved. The alternative form of the sensitivity equation can be used for any point on the radiograph where the ratio of the total to the direct radiation can be determined. A discussion of methods for making approximate calculations of this type is contained in a thesis by Hornbeck[6], as well as in the OSRD report[7]. Where very small fields can be used to examine details of objects, it is possible to obtain lower sensitivities because of the resultant decrease in scattered radiation.

Latitude

Radiographic latitude refers to the thickness range which can be examined with good sensitivity in a single exposure. For steel thicknesses in the straight-line region of the total-beam transmission curves, the following equations hold:

$$\epsilon_{min} = \epsilon_0\, e^{-\mu L}$$

$$L = \frac{2{\cdot}3}{\mu}[\log_{10}\epsilon_0 - \log_{10}\epsilon_{min}] \quad .. \quad (5)$$

where

ϵ_0 = film exposure to give a density of 3 with a given steel thickness;

ϵ_{min} = film exposure for the minimum film density required to give a sensitivity of 1%; and

L = latitude, defined here as that additional thickness of steel examined with a film density sufficient for a sensitivity of 1%, when the given thickness is examined with a density of 3.

(*Concluded on page* 26)

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Economic Aspects of Grinding Sintered Carbide Tools with Diamond Grinding Wheels

By J. WITTHOFF. (From *Technische Mitteilungen Krupp*, Vol. 5, No. 12, September 1954, 15 illustrations.)

It has frequently been pointed out that the use of diamond wheels for grinding sintered carbide tools is advantageous ; thus, for instance, it has been stated that the diamond grains cut through the carbide crystals of sintered carbides, whereas silicon carbide grinding wheels can merely tear carbide crystals from the sintered carbide matrix. The investigations described in this article have been made to ascertain whether, in fact, diamond grinding wheels are more economical.

ALTHOUGH the present investigations of the economic aspects of grinding sintered carbide tools with diamond grinding wheels are not comprehensive enough to enable conclusive opinions to be formed, they have fulfilled their purpose by indicating a method of how such investigations should be carried out and may suggest additional work along these lines. This work should deal particularly with variations in the technique influencing results both technically and economically. Important factors which could not be investigated include grain size of the diamond, dimensions, bond and concentration of grinding wheels, grinding speed, feed, coolant supply, and observation of the grinding process.

As the problem is concerned with cost comparisons, a certain operation, using the same workpiece on a given machine tool under certain working conditions, must be considered. The following investigations deal exclusively with the turning of steel, and it is further assumed that the variations in grinding methods used have no observable influence on the quality and value of the product.

For comparative purposes, all that is necessary is to compare those production costs which in the two cases, i.e., silicon carbide grinding and diamond grinding, are different. These are the tool costs and the costs for tool changes. As the latter are very low, they can be neglected. The tool costs C_t are referred to the individual workpiece and can be determined from the following relation, which has been developed by the author :—

$$C_t = \frac{1}{n_w} \cdot \left(\frac{V_a' - V_u}{n_g + 1} + V_g \right) \quad .. \quad (1)$$

where V_a' is the value of the new tool without grinding costs, V_u the value of the tool at the end of the last operation, n_g the number of regrinds possible, V_g the costs of first grinding or regrinding, and n_w the number of workpieces which can be ground during the tool life, i.e., between two regrinds. The values V_a' and V_u remain unchanged in the cases investigated, and the value of n_g can be taken as constant. V_a' can be determined from the relationship

$$V_a' = V_a - V_g,$$

where V_a represents the tool costs inclusive of grinding. Determination of V_u and n_g does not present any difficulty. There remain, however, the values of V_g and n_w, the calculation of which remains to be discussed :—

Assuming initially that regrinding of tools is carried out at one location only,

$$V_g = W_g \, T_{tg} (1 + r_g) + G \quad .. \quad (2)$$

where W_g is the operator's wage per hour, T_{tg} the total time required for each regrind, r_g grinding-machine overhead factor, excluding grinding-wheel consumption (to be determined separately), and G grinding-wheel consumption costs. The values of W_g, T_{tg}, and r_g can be calculated in the usual way. For calculation of G,

$$G = \frac{t_{ag} (V_{bu} - V_{au})}{t_{tg}} \quad .. \quad (3)$$

where V_{bu} is the value of the grinding wheel before use, V_{au} the value of the wheel after use, t_{ag} the actual grinding time per regrind, and t_{tg} the life of the grinding wheel. For $V_{au} = 0$,

$$G = \frac{t_{ag} \, V_{bu}}{t_{tg}} \quad .. \quad .. \quad (4)$$

The values of t_{ag} and V_{bu} can be determined without difficulty; for the determination of t_{tg} the following should be noted :—By means of preliminary, repeated grinding operations, it is possible to estimate the total grinding time from the weight reduction of the grinding wheel. In these preliminary tests, grinding operations should naturally correspond to those of actual production, so that in both instances satisfactory conformity between grinding-wheel consumption per unit of time can be expected. Admittedly, this method leaves a certain element of doubt in the case of diamond grinding wheels, owing to the fact that the thickness of the " effective layer " cannot be determined exactly. Consequently, data supplied by the wheel manufacturers must be used.

Determination of the weight of the wheel before and after investigations can be made by means of a suitable laboratory balance or from the reduction in diameter (in the case of peripheral grinding wheels) or the thickness (in the case of cup wheels). In the tests to be described, weight reduction was determined by both these methods and satisfactory conformity was observed.

If the tools are reground at different locations, differential partial values G' and G'' must be used for the grinding-wheel consumption G. Then, for r_g an average value must be introduced. In these investigations, initial grinding was always carried out on silicon carbide wheels; thus, the grinding-wheel consumption G' was equal for both comparisons.

The number of workpieces n_w which can be produced between successive regrinds can easily be determined by measuring the wear mark on the clearance face of the tool. To avoid variations, the wear-mark width M' was plotted in relation to the turning time T' of the tool. From this plot, a tool life T for a certain permissible wear-mark width M could be determined equally for both comparison cases, as the machining time t_m for each workpiece is known, and n_w can be determined with reasonable accuracy from

$$n_w = T/t_m \quad .. \quad .. \quad (5)$$

The absolute difference in cost D between two productions can be expressed by

$$D = C_{t1} - C_{t2} \quad .. \quad .. \quad (6)$$

The absolute cost reduction per hour is

$$D' = 60D/t_m \quad .. \quad .. \quad (7)$$

The relative reduction in tool cost D_b is therefore

$$D_b = (C_{t1} - C_{t2})/C_{t1} = 100 \, D/C_{t1}\% \quad (8)$$

The tests were carried out in two groups, I and II, the first comprising three operations of dry diamond grinding. In the second group, six operations were investigated, using wet grinding with a plentiful supply of coolant. In the discussion of the individual tests the operations are indicated as a, b, and c. For each test there are two comparison cases, i.e., silicon carbide grinding and diamond grinding.

RESULTS OF GROUP I TESTS, DRY DIAMOND GRINDING

The operations consisted of longitudinal turning of different steels in various workshops, whilst the tools were always reground under uniform conditions. The grinding wheels used in these tests are given in Table I.

TABLE I. DETAILS OF GRINDING WHEELS AND COSTS OF OPERATION IN TESTS Ia, Ib, AND Ic.

Designation of grinding wheel	Type of grinding operation	Tests	Total grinding time t_{tg}	Cost of grinding wheel V_{bu}	Grinding wheel costs per hr
			hr	DM*	DM/hr*
Silicon carbide peripheral wheel 80 J, 400 mm dia.	initial	Ia to Ic	28	62·5	2·2
Silicon carbide peripheral wheel DGS SC 220-9, 150 mm dia.	chip-breaker	Ia and Ib	6	6·4	1·1
As above	facet	Ia and Ib	10	6·4	0·64
Silicon carbide peripheral wheel 220 L, 150 mm dia.	facet	Ic	10	4·7	0·47
Diamond disc wheel 7 K 11 D 100/75, 80 mm dia.	Chip-breaker	Ia and Ib	32	121	3·8
Diamond cup wheel 1 K 25 D 50/75, 150 mm dia.	facet	Ia to Ic	77	299	3·9

*DM 11·75 = £1.

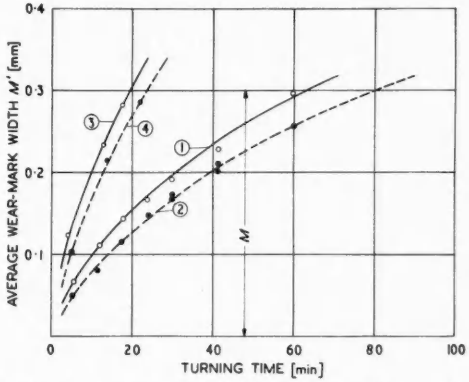


Fig. 1. **Curves of wear-mark width against turning time for Group Ia tests.**
(1) and (3), silicon carbide grinding.
(2) and (4), diamond grinding.
Cutting speed v = 99 m/min (curves (1) and (2)), and 137 m/min (curves (3) and (4)).

RESULTS OF GROUP Ia TESTS, COPY TURNING OF ROLLER BUSHES

For initial grinding in both cases, a silicon carbide peripheral wheel 80 J, of 400 mm diameter and 40 mm width, with sufficient cooling, was used. Subsequently, the chip-breaker groove and the facet on the clearance face were ground. This operation was performed in case 1 with a small silicon carbide peripheral wheel DGS SC 220-9 of porous structure, having a grade K on the Norton scale and a grain size of 220 mesh (diameter 150 mm, width 8 mm). In case 2 the chip-breaker groove was ground in with a resin-bonded diamond cup wheel Superfix 7 K 11 D 100/75 of 80 mm diameter and the facet ground with a resin-bonded diamond cup wheel Superfix 1 K 25 D 50/75 of 150 mm diameter. The grain sizes were D 100 and D 50 respectively and the concentration 75. Diamond grinding was performed without coolant.

After grinding, the cutting edge was honed in case 1 with a silicon carbide hand hone 320-10 and in case 2 with a diamond honing stick of a grain size D 100. The difference was not considered in the cost comparison.

The required grinding times were determined by time study. Details of the times, the grinding wheel consumption, and the cost V_g in DM per regrind are given in Table II. For purposes of comparison, DM 11·75 = £1.

TABLE II. REGRINDING COSTS FROM TEST Ia.

Operation		Case 1 Silicon carbide grinding	Case 2 Diamond grinding
Initial grinding	Designation of grinding wheel	Silicon carbide peripheral wheel 80 J	Silicon carbide peripheral wheel 80 J
	Actual grinding time [min]	1·8	1·8
	Auxiliary time, including lost time [min]	0·7	0·7
Chip-breaker grinding	Designation of grinding wheel	Silicon carbide peripheral wheel DGS SC 220-9	Diamond, disc wheel 7 K 11 D 100/75
	Actual grinding time [min]	2·86	2·38
	Auxiliary time, including lost time [min]	0·35	0·35
Facet grinding	Designation of grinding wheel	Silicon carbide peripheral wheel DGS SC 220-9	Diamond cup wheel 1 K 25 D 50/75
	Actual grinding time [min]	1·03	0·91
	Auxiliary time including lost time [min]	0·10	0·10
	Part time for truing the grinding wheel [min]	1·08	0·03
	Total grinding time, T_{tg} [min]	7·92	6·27
	Hourly wage of operator, W_g [DM/hr]	1·6	1·6
	Overhead factor, r_g	2·7	2·7
	Time-dependent grinding costs [DM] $W_g T_{tg} (1 + r_g)$	0·78	0·61
	Costs of grinding-wheel consumption, G:—		
	G' for initial grinding [DM]	0·067	0·067
	G'' for chip-breaker grinding* [DM]	0·052	0·144
	G''' for facet grinding* [DM]	0·011	0·059
	$G = G' + G'' + G'''$ [DM]	0·13	0·27
	Costs per regrind, V_g [DM]	0·91	0·88

*These values are obtained by multiplying the actual grinding times given in this table by the corresponding grinding-wheel costs from Table I.

TABLE III. NUMBER OF WORKPIECES n_w PRODUCED BETWEEN SUCCESSIVE REGRINDS IN TEST Ia.

Designation	Case 1 Silicon carbide grinding		Case 2 Diamond grinding	
Cutting speed, v [m/min]	99	137	99	137
Tool life, T [min]	65	20	82	25
Machining time, t [min]	0·30	0·22	0·30	0·22
$n_w = T/t_m$	217	91	273	113

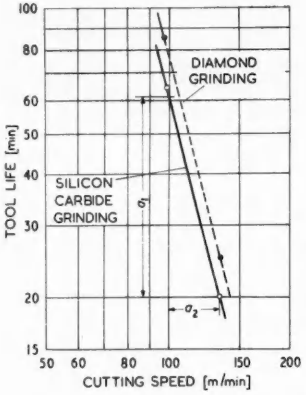


Fig. 2. **Tool-life curves for Group Ia tests.**
Wear-mark width $M = 0{\cdot}3$ mm.
Inclination $a_1/a_2 = -3{\cdot}8$.

Fig. 1 shows the course of the wear-mark width, from which the tool-life curves in Fig. 2 have been plotted. The data for a wear-mark width of 0·3 mm are given in Table III.

Determination of the tool costs C_t from eq. (1) shows considerable savings in the case of diamond grinding. These savings are given in Table IV.

TABLE IV. SAVINGS IN TOOL COSTS C_t FROM TEST Ia.

Designation	Case 1 Silicon carbide grinding		Case 2 Diamond grinding	
Value of tool when new, V_a' [DM]	6·15		6·15	
Value of tool after use, V_u [DM]	0		0	
No. of regrinding operations, n_g	10		10	
Cost of regrinding, V_g (from Table II) [DM]	0·91		0·88	
Cutting speed, v [m/min]	99	137	99	137
Tool cost per workpiece, C_t [DM]	0·00675	0·016	0·0052	0·0127
Absolute saving D for the workpiece in case 2 [DM]	—	—	0·00155	0·0033
Absolute saving D' per hour machining time in case 2 [DM/hr]	—	—	0·31	0·90
Savings in case 2, D_b [%]	—	—	23	21

RESULTS OF GROUP Ib TESTS, COPY TURNING OF SHAFTS

Distinction is made between the following grinding operations:

(1) Initial grinding with a peripheral silicon carbide wheel, (2) chip-breaker groove grinding, and (3) facet grinding.

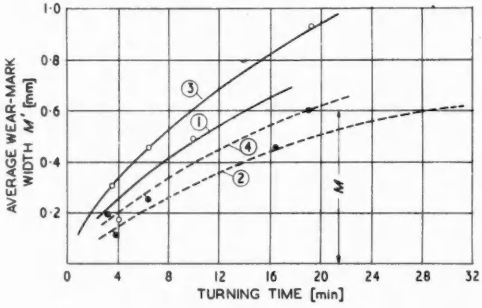


Fig. 3. **Curves of wear-mark width against turning time for Group Ib tests.**
(1) and (3), silicon carbide grinding.
(2) and (4), diamond grinding.
Cutting speed $v = 126$ m/min (curves (1) and (2)), and 160 m/min (curves (3) and (4)).

TABLE V. SAVINGS IN TOOL COSTS C_t FROM TESTS Ib AND Ic.

Designation	Test Ib				Test Ic	
	Case 1 Silicon carbide grinding		Case 2 Diamond grinding		Case 1 Silicon carbide grinding	Case 2 Diamond grinding
Value of tool when new, V_a' [DM]	21·6		21·6		9·3	9·3
Value of tool after use, V_u [DM]	0		0		0	0
No. of regrinding operations, n_g	13		13		12	12
Cost of regrinding, V_g [DM]	1·21		1·15		0·48	0·51
Cutting speed, v [m/min]	126	160	126	160	140	140
No. of workpieces per tool life, n_w	10	15	37	31	4·0	7·9
Tool cost per workpiece, C_t [DM]	0·14	0·18	0·060	0·071	0·30	0·15
Absolute saving D for the workpiece in case 2 [DM]	—	—	0·080	0·109	—	0·15
Absolute saving D' per hour machining time in case 2 [DM/hr]	—	—	6·2	10·6	—	4·05
Savings in case 2, D_b [%]	—	—	57	61	—	50

The operations according to (1) are the same in both cases. The operations according to (2) and (3) are either performed with a silicon carbide or a diamond grinding wheel. In all instances, the same grinding wheels as for group Ia tests were used. The cost V_g per regrind, the value of n_w, the tool cost C_t, and the savings obtained are given in Table V. The wear-mark width curves are given in Fig. 3 for a wear-mark width of 0·6 mm.

RESULTS OF GROUP Ic TESTS, ROUGHING OF SHAFTS

The tools were reground as follows :—

(1) Initial grinding with the silicon carbide grinding wheels used in tests Ia and Ib, and (2) grinding of a facet on the clearance face.

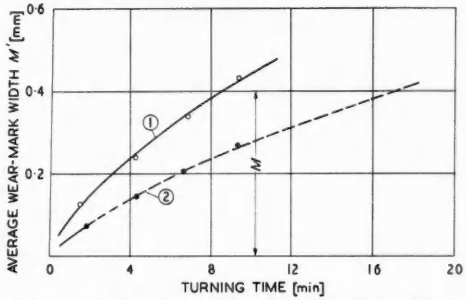


Fig. 4. **Curves of wear-mark width against turning time for Group Ic tests.**
(1), silicon carbide grinding. (2), diamond grinding.

A chip-breaker groove was not provided. Different wheels were used only in grinding operations (2). For case 1, a silicon carbide peripheral wheel 220-L of 150 mm diameter, and for case 2 the already mentioned diamond cup wheel 1 K 25 D 50/75, were used. All necessary data are given in Table V. The wear-mark width/tool-life curves for a wear-mark width of 0·4 mm are given in Fig. 4.

RESULTS OF GROUP II TESTS, WET DIAMOND GRINDING

Rough and finish turning of locomotive axles was investigated on various lathes. The corresponding details are given in Table VI. Bronze-bonded diamond

grinding wheels, " Superfix," of grain sizes D 100 and concentrations 100 and 75 respectively, were used. The investigations were carried out in a similar way to those of Group I. The main difference was that water, with an addition of a rust inhibitor, in the ratio of 1:100, was used. Furthermore, the chip-breaker grooves were ground in one pass when using diamond grinding wheels.

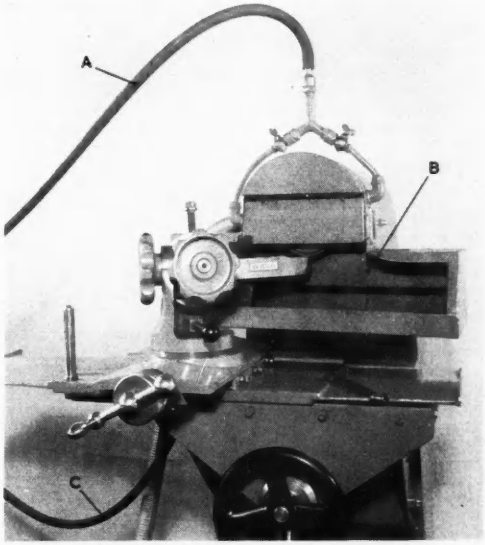


Fig. 5. **Chip-breaker grinding machine, modified for wet grinding.**
(A) coolant supply; (B) splash guard; (C) coolant outlet.

When grinding the facet, the coolant could be supplied without difficulties but the chip-breaker grinder had to be modified for wet grinding, as shown in Fig. 5.

Results of Group IIa to IIf Tests, Turning of Locomotive Axles

When determining costs per regrind, a value of DM 2·68 was obtained for silicon carbide grinding and DM 1·27 for diamond grinding. The curves of the average wear-mark width in relation to turning time for test IIf are shown in Fig. 6. Fig. 7 shows the tool-life/cutting-speed diagram for the same test.

Table VI. Details of Grinding Wheels and Costs of Operation in Tests IIa to IIf.

Designation of grinding wheel	Grinding operation	Tests	Total grinding time t_{tg}	Cost of grinding wheel V_{bu}	Grinding wheel costs per hr
			hr	DM	DM/hr
Silicon carbide peripheral wheel DGS SC 80-8, 400 mm dia.	initial	IIa to IIf	28	62·50	2·2
Silicon carbide grinding cylinder DGS SC 80-5, 350 mm dia.	initial	IIa to IIf	18	83·13	4·62
Silicon carbide peripheral wheel DGS SC 80-5, 125 mm dia.	chip-breaker	IId to IIe	1·1	4·50	4·10
Silicon carbide peripheral wheel SGS SC 180-5, 125 mm dia.	chip-breaker	IIa to IIf	1·78	4·20	2·36
Silicon carbide grinding cylinder 200 L, 140 mm dia.	facet	IIa to IIf	3·5	7·12	2·13
Diamond peripheral wheel 12 Br 17 D 100/100, 100 mm dia.	chip-breaker	IIa to IIf	132	335·80	2·52
Diamond cup wheel 1 Br 26 D 100/75, 150 mm dia.	facet	IIa to IIf	188	569·80	3·02

DISCUSSION OF RESULTS

In Table VII the values of V_g and n_w, as well as their variations with tool cost C_t, are compared for all tests.

General conclusions:—

(1) A clear survey of the conditions can be obtained only if, in both comparison cases, the tool costs are determined with full consideration of all influential factors.

(2) The economy of diamond grinding is clearly shown from the values presented in Table VII. The relative savings D_b in tool costs are between 21 and 65%, i.e., very considerable.

(3) The savings obtained are due to a great extent to the increase in tool life with diamond grinding, i.e., an increase in these tests of between 24 and 115%. The question of the causes of this improvement in tool life still remains to be answered.

(4) The figures presented do not show that with silicon carbide grinding the risk of crack formation is considerably higher than with diamond grinding.

Table VII. Values of V_g and n_w, and their variations with Tool Cost C_t, for all Tests.

	Test	Cutting speed, v	Cost V_g per regrind		Relative reduction in costs, V_g in case 2	No. of work-pieces n_w per tool life		Percentage increase of n_w in case 2	Percentage reduction D_b of tool costs C_t in case 2
			Case 1 Silicon carbide grinding	Case 2 Diamond grinding		Case 1 Silicon carbide grinding	Case 2 Diamond grinding		
		m/min	DM	DM	%			%	%
Comparison between silicon carbide and dry diamond grinding	Ia	99	0·91	0·88	3·3	217	273	26	23
		137	0·91	0·88	3·3	91	113	24	21
	Ib	126	1·21	1·15	5·0	19	37	95	57
		160	1·21	1·15	5·0	15	31	107	61
	Ic	140	0·48	0·51	—6·2	4·0	7·9	98	50
Comparison between silicon carbide and wet diamond grinding	IIa	210	1·18	0·62	47	9·7	16·9	75	57
	IIb	192	1·18	0·62	47	3·7	8·0	115	65
	IIc	210	1·18	0·62	47	4·1	7·3	78	57
	IId	110 to 160	2·68	1·27	52	4·2	8·4	100	63
	IIe	83 to 90	2·68	1·27	52	5·1	9·0	77	58
	IIf	145	1·18	0·62	47	6·5	10·3	59	52
		192	1·18	0·62	47	2·8	5·9	109	64
		230	1·18	0·62	47	1·9	3·8	100	62

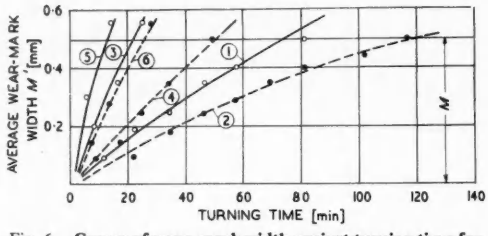


Fig. 6. **Curves of wear-mark width against turning time for Group IIf tests.**
(1), (3), and (5), silicon carbide grinding.
(2), (4), and (6), diamond grinding.
Cutting speed v = 145 m/min (curves (1) and (2)), 192 m/min (curves (3) and (4)), and 230 m/min (curves (5) and (6)).

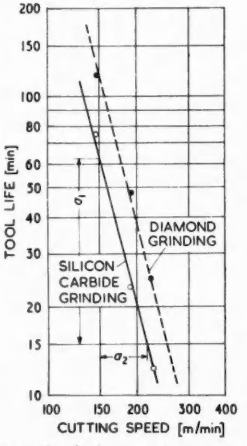


Fig. 7. **Tool-life curves for Group IIf tests.**
Wear-mark width M = 0·5 mm.
Inclination a_1/a_2 = — 3·9.

(5) It should be mentioned that only such operations were investigated for which, in Germany, regrinding on diamond grinding wheels is not at present general practice.
(6) Total cost reductions will be increased if the share of the tool costs in total production costs is increased. This applies particularly to cases where several expensive tools are used, as against the present tests with simple tools.
(7) A change from silicon carbide grinding to diamond grinding merits special consideration, if several work stations are provided in the same workshop.
(8) Differences in tool-changing costs have not been considered. These would give additional savings in the case of diamond grinding.
(9) Of importance is the uniform position of the measuring points for plotting the wear-mark width/tool-life curves. The difference in inclination a_1/a_2 of the straight lines in Figs. 2 and 7 is insignificant.

Special Advantages of Wet Diamond Grinding :—

(1) From the costs V_g per regrind in Group I (see Table II) the costs of grinding-wheel consumption with diamond grinding wheels are considerably higher than those with silicon carbide grinding wheels. In spite of this, however, the cost V_g is approximately the same in the cases compared. This is due to the fact that the grinding costs per unit of time are considerably higher than the grinding-wheel consumption costs G and on balance lead to lower values for diamond grinding. In contrast, wet diamond grinding has the advantage that both time-dependent costs, as well as grinding wheel consumption costs, are considerably reduced.

Whilst the relative reduction in V_g in Group I (Table VII) is between +5·0 and −6·2%, in test group II it is between +47 and +52%.

(2) The saving in grinding costs is of particular importance in chip-breaker grinding. Grinding times are reduced from 13·2 min to 3 min and the grinding-wheel costs from DM 0·49 to DM 0·105. It must, however, be mentioned that correct grinding of chip-breaker grooves in one pass is a delicate operation. If these conditions are not fulfilled, grinding cracks can occur.
(3) In general, wet grinding with bronze-bonded diamond grinding wheels brings considerable additional advantages, compared with dry grinding on resin-bonded wheels, and contributes to the savings shown in Table VII.
(4) In the Group I tests for facet grinding a diamond cup wheel with a grain size D 50 was used, as compared with a peripheral diamond grinding wheel with a grain size D 100 in the Group II tests. In spite of this relatively coarse grain, satisfactory results were obtained.

RADIOGRAPHIC PROPERTIES OF X-RAYS IN THE RANGE BETWEEN TWO AND SIX MEGAVOLTS

(*Concluded from page* 21)

The difference expressed in the brackets of eq. (5) can be found for each steel thickness, as follows:— The minimum values of film gamma γ are calculated by substituting S = 0·01 in eq. (3) and solving for different thicknesses. Then, the required densities are found from a curve of γ *versus* density for the film used[8]. Finally, the difference in log exposure for density 3 and for each minimum density is given by the characteristic curve of the film. This definition of latitude is similar to that adopted by the OSRD group. The selection of a maximum sensitivity of 1% was arbitrary, and the maximum density of 3 was chosen because this is the upper limit of ordinary fluorescent viewers. Although the latitude is certainly increased by the use of greater densities and high-intensity viewers, definition is at present sufficient for a comparison of the latitudes obtained with different tube voltages.

Definition

Definition refers to the sharpness of reproduction on a film of a particular discontinuity in the object radiographed. Simple geometric considerations result in

$$c = st/d \quad .. \quad .. \quad .. \quad (6)$$

where c = the diameter of circle of confusion; s = the diameter of focal spot; d = the target-to-defect distance; and t = the defect-to-film distance.

A dimensionless point in the object will appear as a circle of diameter c in the radiograph. For a sharp picture it is important to have a small focal spot and as large a ratio of d/t as is reasonable from the point of view of exposure time. Since the electron beam from a Van de Graaff accelerator is homogeneous in energy, a simple annular magnet around the tube extension can be used to focus the spot to minimum diameters of the order of 0·01 in. Other factors besides geometry which ultimately limit the resolution of the radiograph are the film-grain size and the range of the secondary electrons in the emulsion. Only pair-production and Compton electrons, which are scattered at wide angles to the X-ray beam, are effective in spreading the image in the emulsion. Although the energy of these electrons increases with photon energy, the probability of their having wide angles decreases. The limit in resolution caused by the range of these electrons at 2-million volts is also about 0·004 in. Although this limit has increased at 6-million volts, substantially higher voltages are required to make this phenomenon a practical limitation.

British Industrial Developments

Heat Exchangers Incorporating Longitudinally Finned Tubes

Heat exchangers incorporating longitudinally finned tubes have been widely used throughout the petroleum, chemical, and allied industries for many years in America; moreover, some few examples have been imported into this country in recent years. During the past few months, however, Brown Fintube (Great Britain) Ltd., have been manufacturing fintubes and fintube heat exchangers at their Birmingham works, and several installations are now in operation in some of the major British refineries.

In the construction of a fintube two requirements must be met:—The fins must be perfectly bonded to the tube, and the tube wall must not be weakened in any way. This rules out any mere mechanical bond, and the method of construction used in the Brown fintube efficiently solves these problems. The fins are formed in pairs from flat strip by rolling the latter into a truncated "V," which is then welded or brazed to the outer surface of the tube. The resulting fintube is thus of completely integral construction, and detachment of the fins is impossible without actually destroying them Continuous welding is used for ferrous materials, and brazing for non-ferrous materials, using patented special machines and techniques built up over many years of experience by The Brown Fintube Company of America. A typical fintube is illustrated in Fig. 1.

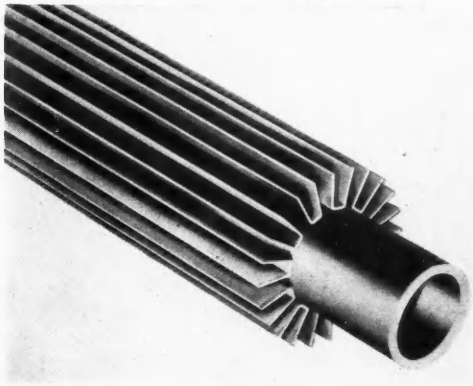


Fig. 1.

The ratio of outside surface to inside surface can be extremely high; indeed, ratios of 8:1 or over are frequently used. The actual ratio used depends entirely upon the required duty of the exchanger and the fluids involved. The suitability of extended-surface heat exchangers is largely governed by the comparative rates of heat transfer for the fluids under consideration; should there be an appreciable difference in the heat-transfer coefficients between the exchanging fluids, the use of finned-surface exchangers should receive serious consideration. A ratio between the two coefficients of 3:1 or better indicates that extended surfaces should be used.

Double-pipe heat exchangers have come more into general use in recent years as the advantages of this type of exchanger have become better known. The most frequently used form of the double-pipe exchanger is the "hairpin" section, which permits easy connection of the number of sections required into a compact bank capable of performing almost any heat-transfer duty. Generally speaking, the best application of the longitudinally finned double-pipe hairpin exchanger is in transferring heat between two fluids with unequal heat-transfer characteristics; the purpose of employing what is, in effect, unequal surfaces on the two sides of the tube is to help balance out the heat-transfer characteristics of the two dissimilar fluids, so that each fluid will have, as far as possible, the optimum surface for picking up or giving up heat.

Allied to such considerations is the relativity of the film coefficient to the thermal conductivity of the fins; with high film coefficients the advantage of the extended surface, which may be expressed as fin efficiency, is less than it is with low film coefficients on the finned side. This effect, which is a function of temperature gradient from fin root to fin tip, results in a lower heat density per unit surface and is frequently turned to advantage when dealing with heat-sensitive fluids or fluids liable to coking.

Many examples of the sphere of usefulness of longitudinally finned tubes can be quoted from actual practice, e.g., steam to fuel-oil heaters of the tank-suction or line type for reducing the viscosity of oil stored in tanks, so as to facilitate pumping and transportation through pipe lines; product condensers and coolers, using water as the cooling medium; product re-boilers, using steam or a reactor effluent vapour as the heating medium; air heaters or coolers, particularly intercoolers and after-coolers; and oil- or gas-fired heaters, using finned surfaces to help diffuse the radiant heat from the flame to the heated fluid. A particularly interesting use of finned steam heaters is for storage-tank heating. Vertical fintubes manifolded together as units (Fig. 2) are situated in the tank, fed by inlet and outlet steam lines. One or more units are employed, arranged in a ring formation, depending upon the size of the tank and the nature of its contents. The effect of these heaters is to create a convection flow in the tank contents as the heated fluid rises; thus, in addition to heating the contents, the latter is perpetually in slight motion, avoiding stratification and minimising sedimentation.

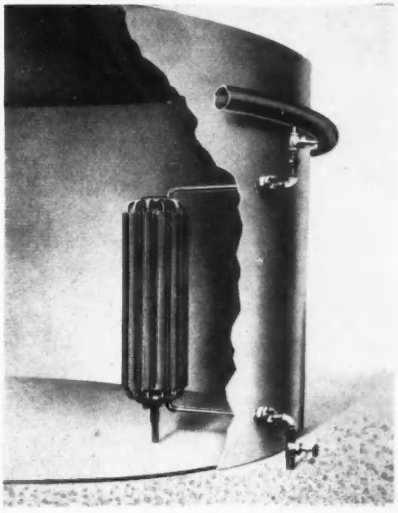


Fig. 2.

Such heaters are frequently employed in conjunction with tank suction heaters. Portable heaters of this type can also be usefully employed to facilitate the emptying of tank wagons or road tankers.

It will thus be seen that the greatest field of usefulness for extended-surface equipment is transfer of heat from a fluid of low viscosity from or to a relatively viscous fluid. However, longitudinally finned double-pipe hairpin exchangers have also been used extensively in transferring heat between two fluids with similar heat-transfer characteristics. In these cases, the tube-side fluid generally flows at high velocity, utilising the maximum permissible pressure drop to obtain the best heat-transfer coefficient possible, whilst the fin-side fluid may flow at moderate velocities.

The most versatile type of extended surface exchanger is the hairpin-type sectional exchanger referred to previously. These units are extremely flexible and can be manifolded into any required arrangement of series and parallel flows to perform any given duty; thus, variations in duty requirements can be catered for by cutting sections in or out of the stream. This versatility can be utilised to further standardisation. A whole plant can be equipped with heat exchangers of one or two standard sizes only, the sole difference between the various exchangers being the number of sections and the banking arrangements. Shortly to go into service in a Continental refinery is a new platformer, of which the stabiliser unit will have all its exchangers supplied by Brown Fintube (Great Britain) Ltd.; only two sizes are involved, although there are six items, some duplicated, involving over 40 sectional units. Not only does this reduce the amount of spares to be carried to ensure complete stores cover, but the small size and low weight of these units greatly facilitate routine maintenance. Two men, with no lifting tackle, can remove and replace an inner element in approximately one hour.

The general construction is simple, consisting of a U-tube shell with a U-tube inner element, finned or plain, as dictated by service requirements. At the return-bend end, the cover plate can be provided with a tongued and grooved joint for high-pressure services. The shell/tube seal is particularly suited for hazardous fluid services, as there is no possibility of leakage of either fluid. Taper surface joints, which might become damaged during maintenance, are avoided.

The standard range of sections gives surface areas ranging from 3 to over 250 sq ft per single hairpin section. Pressure ratings are standardised for 600, 1200, and 1800 psi on the shell side; much higher pressures can also be accommodated inside the tube, some having been designed for 10,000 psi for special services.

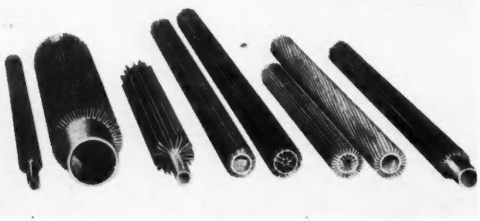


Fig. 3.

These exchangers are available in a wide range of sizes and types, some of which are illustrated in Fig. 3. Furthermore, they can be supplied in all materials, including carbon steel, chrome-molybdenum steel, stainless steel, Admiralty brass, cupro-nickel, aluminium brass, monel, inconel, and aluminium. Design is based on the API-ASME Code, but all other codes can be catered for.

The design and construction of the entire range of Brown Fintube products follows established oil-refinery and chemical practice, and manufacture is carried out by personnel accustomed to exacting work to Lloyd's Register Class II standards. Moreover, in this connection, it is stressed that the Company is fully qualified to design and manufacture fintubes for any special application, as required.

A Modern Temper-Mill Drive

After cold reduction to finished gauge, coils of steel strip are usually subjected to a stage of skin-passing in a temper mill to impart to the steel the desired mechanical properties and surface finish. To ensure uniformity in the finished product, the selected tension must be maintained throughout the temper-rolling process, including the periods of acceleration and deceleration of the mill, and must not be affected by the changing diameters of the coils as the strip is unwound and reeled. The essential features of a satisfactory control scheme for a temper mill are therefore high speed of response, together with adequate sensitivity and stability.

At the Courtybella Works of the Whitehead Iron and Steel Co. Ltd., Newport, where a new 21-in. single-stand, 4-high temper mill has recently been commissioned, these requirements have been met by adopting a control scheme comprising a Ward Leonard system operating in conjunction with control exciters. The temper mill was supplied by the Davy & United Engineering Co. Ltd., and the whole of the electrical plant and control gear by The General Electric Co. Ltd.

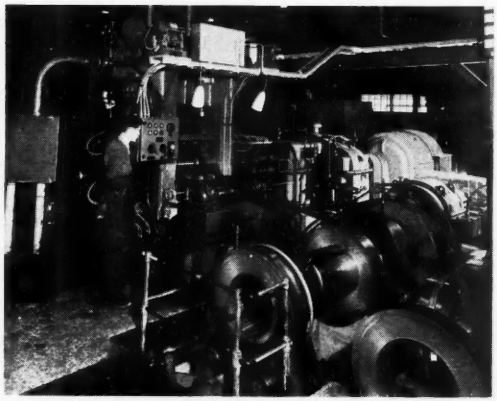


Fig. 1.

A general view of the mill from the entry side is shown in Fig. 1. The uncoiler in the foreground is coupled through gearing to a drag generator rated at 50 kW, 0/350/350 V, 0/300/950 rpm, and the mill rolls are driven through reduction gears by a d.c. motor rated at 0/200/200 hp, 0/250 V, 0/300/750 rpm. On the delivery side of the mill (Fig. 2), the coiler shown on the left is driven through reduction gearing by an 0/150/150-hp, 0/350/350-V, 0/300/750-rpm, d.c. motor equipped with an electromagnetic brake. The motors are fitted with pedestal journal bearings arranged for oil-ring lubrication, and the drag generator with end-shield ball and roller bearings. All three machines are forced-ventilated with cooling air supplied by a 27-in. diameter fan driven by a 5-hp motor.

Direct-current supply for the mill drives is obtained from a motor-generator set installed in a substation adjacent to the mill. The set comprises a 435-hp, 6-kV slipring induction motor running at 970 rpm, direct-coupled to a d.c generator with an output of 0/300 kW at 0/250 V. A totally enclosed liquid starter is provided for the motor.

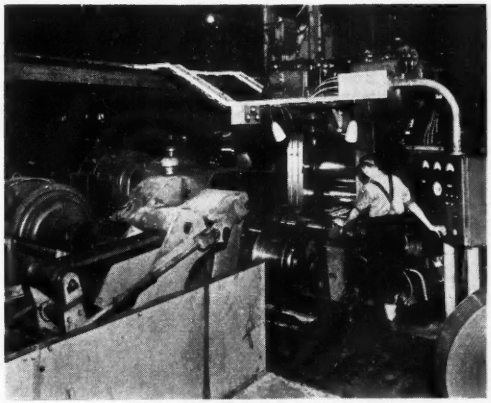


Fig. 2.

For the control of the mill drives, three smaller motor-generator sets are provided. The first consists of a 70-hp, 1450-rpm squirrel-cage motor driving a 37-kW delivery-reel booster, a 20-kW entry-reel booster, and a 9·5-kW constant-voltage exciter; the two remaining sets are groups of four control exciters driven at 2900 rpm by 6-hp motors. The three sets are mounted in the substation adjacent to the low-voltage switchboard (Fig. 3). Control cabinets are fitted to the entry and delivery sides of the mill. Both cabinets are equipped with drive-selector switches, "inch" controllers, emergency stop buttons, and indicator lamps, while in addition the delivery cabinet is fitted with a 5-position "run" controller, as well as selector and controller switches for the mill screwdown drives.

The G.E.C. control exciter which forms the basis of the control scheme for the mill is fundamentally a standard d.c. generator with conventional armature windings and brushgear. It differs from the standard machine in that its magnetic circuit is completely laminated, and that a number of separate field windings is provided for the various control and stability circuits. In this application the control exciters, in addition to meeting the essential requirements already outlined, provide a control scheme which enables coils of a wide range of widths and thicknesses to be processed. The control scheme is designed to take care of all requirements efficiently and positively, including overall speed control, constant strip tension, delivery-end control, entry tension control, acceleration compensation, and strip breakage.

Fig. 3.

Segas Plant

The Eastern Gas Board has recently placed an order with The Power-Gas Corporation Ltd., of Stockton-on-Tees, for a SEGAS installation at Ponders End Works, comprising one unit to produce 3,200,000 cu ft of gas per day, together with all necessary ancillary equipment, gas cooling, and naphthalene removal plant. The scheme is laid out for future extension.

This order may be claimed to represent an important step forward in the development of the SEGAS process, since it will be a unit embodying all the accumulated experience gained in the operation of the Sydenham and York plants, which were to some extent prototype units.

The process orginated in the laboratories of the former South Metropolitan Gas Company and, under nationalisation, the work was continued by the South Eastern Gas Board. In due course an agreement was made whereby The Power-Gas Corporation Ltd. became the sole licensee for the commercial development of the process. The plant is designed to produce from oil a gas with calorific value, specific gravity, and combustion characteristics similar to those of towns gas. The gas produced is, in fact, interchangeable with towns gas, thus giving wide flexibility either in the mixing of its output with other gas streams or even in replacing them altogether.

The unit at Sydenham was the first SEGAS catalytic oil-gas plant in Britain to produce towns gas from oil on a commercial scale, and over 600,000 gallons of heavy fuel oil have already been used. The York plant has shown itself to be equally efficient. These two units, however, are of the three-vessel type, whereas the plant to be installed at Ponders End will have two vessels and will incorporate a vaporising chamber to make even more efficient the vaporisation of heavy fuel oil in steam before it reaches the catalyst bed. This modification of design, together with its greatly increased capacity compared with the two former units, gives the Ponders End project special significance.

A waste-heat boiler fitted with ancillary oil burners will provide all steam requirements. Turbine-driven air blowers will take the steam and exhaust into a low-pressure system from which, in turn, the process-steam requirements of the plant are drawn. Provision is made for a cooling tower, over which the scrubbing liquid for the direct-contact washer cooler is circulated. This will not only reduce the amount of effluent for disposal to a minimum but will help to improve the quality of such effluent. It is most important in these days to avoid difficulties due to effluent disposal and this aspect of the plant has thus received very especial consideration.

Tar treatment will be carried out by using surface-active agents, as experience has shown that these are effective in reducing the water content of tar from SEGAS plant to less than 5% without further treatment. Such tar is acceptable to chemical plants as a saleable product, or it may be used as burner fuel, a possibility which is arranged for in the Ponders End plant.

An interesting point is that extension of the plant will permit the installation of a steam-driven generator set working, like the air blower turbines, from the high- to the low-pressure steam system; this will provide power in excess of the requirements of electrically driven plant units, thus aiding the overall economy of the process.

The Ponders End plant will be the first installation constructed by The Power-Gas Corporation Ltd. which has not been constructed specifically for development purposes. It will be in full operation in 1956.

Continuous-Acting Hydraulic Intensifier

A portable continuous-acting hydraulic intensifier unit, the purpose of which is to produce high-pressure fluid from a low-pressure fluid supply, has been developed by Fawcett Preston and Company Limited, of Bromborough, Cheshire.

The outstanding feature of this apparatus is the electrical control system, patent for which is pending. It is the first time that such a system of electrical control has been applied to a hydraulic intensifier unit, the latter, of course, being a common item of hydraulic equipment. The unit has been attractively designed and the entire apparatus, as shown in Fig. 1, is encased in a compact sheet-steel cabinet (*A*). The lower portion contains the oil reservoir (*B*), and is supported on six caster wheels. The end front panel houses the electrical controls, consisting of push buttons, indicator lighting, and contact gauges, while the delivery pressure line (*C*) (Fig. 2), plus the bayonet-type electrical socket (*D*) is located on the opposite side of the casing. The convenience of having a mobile unit of this type which can be taken to any convenient position where electrical points are available will be appreciated.

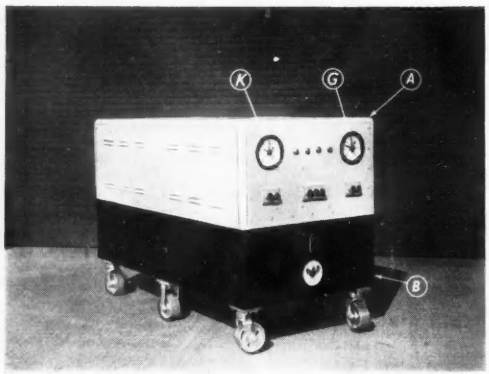


Fig. 1.

The function of the intensifier is more of less orthodox, but the control is quite special. The L.P. cylinder (*E*) (Fig. 3) is in a central position with two H.P. cylinders (*F*), one on either side. Low-pressure fluid (oil) is introduced to the annular area and moves the intensifier piston to one side, thus displacing fluid (either water or oil) on the opposite side of the H.P. piston through the H.P. delivery valve to the ultimate testpiece or press cylinder.

There are two L.P. annuli and, while one is subjected to low pressure from the pump—as in this case—and the piston is moving out, the other annulus is discharging through a valve back to the oil reservoir. The fluid in the L.P. circuit is oil, but the H.P. circuit of this intensifier can be oil or water. The intensification of pressures is directly proportional to the area of the L.P. annulus and the H.P. piston. However, when using oil for L.P. and H.P., a higher output pressure can be obtained than with water for the same inlet pressure, as the L.P. oil is fed to both the smaller piston and the larger annulus.

The L.P. pump output is controlled by an electric pressure gauge (*G*) (Fig. 1) which actuates the solenoid-operated pilot valve (*H*) (Fig. 3), which in turn controls the unloading valve. The oil output can therefore be by-passed at any setting from zero to 1500 psi. The delivery side of the low-pressure pump is fitted with a non-return valve and an adjustable valve to safeguard against overloading.

A suction valve (*I*) and a delivery valve (*J*) (Fig. 3) are fitted in the H.P. intensifier system, connected up by piping to both H.P. cylinders. The contact pressure gauge (*K*) (Fig. 1) in this line can be set to any predetermined maximum pressure and when actuated will break the electrical circuit controlling the solenoid of the main L.P. two-way valve (*L*) (Fig. 2), thereby causing this valve to take up a neutral position and consequently stopping the reciprocating movement of the intensifier itself. The intensifier can therefore be set in any desired horizontal or vertical position.

The electrical control gear is housed completely within this portable unit, and all hand controls are fitted in the end panel. This gear consists in essence of two electrical pressure gauges, one L.P. and one H.P., with electric contactor relays energising in turn the various solenoid-operated valves with their corresponding limit switches (*M*) (Fig. 3). "Stop" and "Start" push buttons operate the L.P. pump-motor starter, the pump output automatically circulating through the unloading valves. Auxiliary buttons are provided, to enable the operator to "inch" the intensifier if required, or stroke the intensifier independently, as opposed to the fully automatic cycle.

It is important to note that, by setting the contacts on either the low- or high-pressure electric gauges, the intensifier can be made to operate at any intermediate pressure from zero to maximum within its range. An electric motor (*N*) and control box (*O*) (Fig. 2) are wired to the electrical supply, 415 V, 3-phase and neutral, splitting the 3-phase supply to give single-phase voltage for the control panel.

The Fawcett intensifier offers a very convenient means of supply for high-pressure hydraulic testing of cylinders, vessels, pipes, tubes, hose, etc. For oil

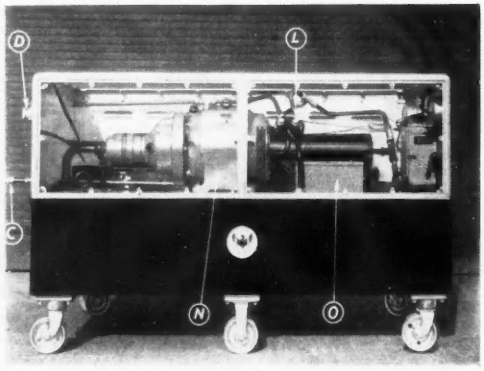


Fig. 2.

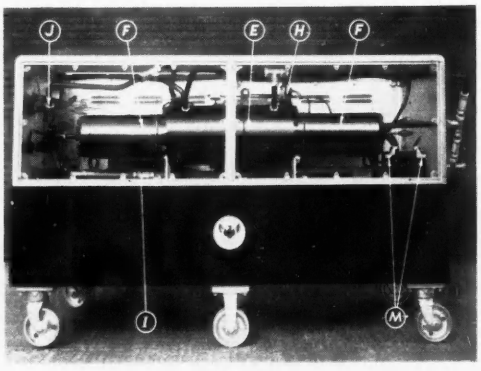


Fig. 3.

applications above 5000 psi, and up to 8000 psi, the intensifier unit is more economical than direct pumping for pump outputs above 5 gpm. From 8000 to 10,000 psi the intensifier will always be cheaper, and above 10,000 psi the intensifier is essential. It will replace existing two-stage pumping units, depending on the hydraulic application. Many press applications require a long stroke of the main arm under light load and then apply the short-stroke high-pressure squeeze. On down-stroking presses this is normally carried out by a pre-filling tank and valve, but on all upstroking presses of modern design the two-stage pump is at present utilised. For the operation of a battery of presses, the low pressure can be utilised in conjunction with an accumulator to supply a ring main to the presses with a great saving in horse power and initial cost. Each press can then be fitted with an intensifier which is used only when full power is required.

Although designed essentially as a high-pressure unit, the intensifier itself may be used for medium pressures in some instances. It can be used with slight modifications to obtain the following variations:—(1) Low-pressure oil inlet to give high-pressure oil outlet; (2) low-pressure oil inlet to give high-pressure water outlet; (3) low-pressure water inlet to give high-pressure water outlet.

The low-pressure pump is driven by a 10-hp electric motor delivering 8 gallons of oil per minute up to a normal pressure of 1500 psi. When using oil on the output side, the intensification ratio is 5½ to 1, i.e., a normal output pressure of 8250 psi. When water is the medium on the output side, the intensification ratio is 4 to 1, i.e., a normal output pressure of 6000 psi. Actually, this prototype machine has been tested for short periods above the normal pressure up to 9000 psi.

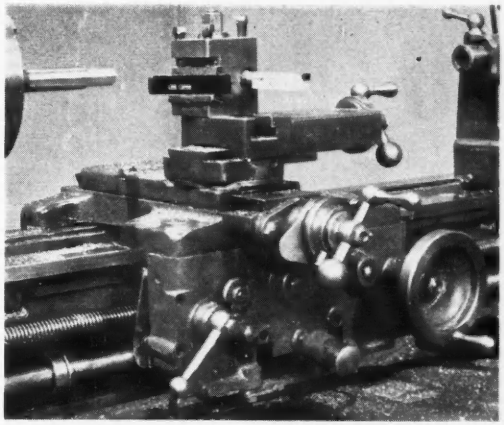
High-Speed Threading Device for Centre Lathes

Considerable interest has been shown in a new high-speed threading device for centre lathes, which appears eminently suitable for incorporation in new designs and which will also be made available in attachment form for existing machines in the near future.

As the invention controls the operation mechanically, screw cutting at speeds suitable for tungsten carbide tools presents no difficulty, even for unskilled operators. In its complete form, it enables a thread of any pitch—English, metric, etc.—to be cut at speed with any leadscrew, whether it be an external thread finished tight to a shoulder or a blind internal thread. The initial invention was a simple indicating device for attachment on the lathe bed, where it is in contact with the leadscrew and spindle. With it, any thread can be picked up at will in the normal manner on a standard lathe at around 200 rpm, thus simplifying internal threading or working to a shoulder, particularly as the device also indicates the point of disengagement.

Another threading problem—depth of cut—was solved by equally simple means. A spring-loaded plunger let into the body of the cross-slide engages a circle of "dimples" on one side of a diamond-shaped plate, as shown in the illustration; this plate is freely mounted over the feed screw and engages a stop pin in the micrometer scale. The "dimples" are spaced to correspond with the graduations on the scale. The device was designed so that the feed screw can be withdrawn up to one revolution for traversing without disturbing the setting of the plate, which thus records the preceding position of the tool, so that it can be quickly and accurately returned. The depth of cut is increased merely by counting the "clicks" of the plunger. The plate can be totally disengaged, as desired.

This, with the original indicator, eliminated the problems of thread chasing and so started experiments in high-speed operation. Mechanism based on the principle



used in the original indicating device was built into the gears and connected to the apron by a cable, so that engagement of the nut with the leadscrew is possible only at the correct moment.

The next problem was automatic disengagement, since it was impossible to terminate the cut by hand at speed. The nut mechanism was re-designed, with the nut spring-loaded in the direction of disengagement, and with locking on the leadscrew by a pawl until the carriage reaches a stop collar, adjustable along the leadscrew or feed shaft. The nut, of course, can be disengaged by hand at any point.

A simpler design of pick-up mechanism was developed, chiefly for an attachment version for existing machines. In this design, engagement of the nut is controlled by an index plate, which is located to the right of the operating lever. This system has the advantage of being entirely contained in the apron, but it is confined to English pitches on an English leadscrew. For threading, a pin is inserted through the front of the apron into the nut mechanism, and when the operating lever is raised this pin rides on the periphery of the index plate until it coincides with one of the slots as the plate is rotated by a pinion meshed with the leadscrew. The mechanism is so designed that the engagement position is easily found on the operating lever, and can thus be operated with ease at a high speed, e.g., 1750 rpm.

The weight of the saddle mass is approximately balanced by the friction of the pin on the periphery of the index plate, with a consequent tendency to start it in motion, owing to the retarding of the pinion on the leadscrew. As the pin enters a slot, the carriage begins to move smoothly on the locked pinion before the nut engages the leadscrew.

Messrs. Wickman, of Coventry, using "Wimet" single-point V-form tungsten carbide tools on steel, carried out tests within the limits imposed by the power unit, and report:—"It is evident that a considerable step forward has been made in the operation of thread chasing, enabling much higher speeds to be obtained and completely relieving the element of chance previously present. The higher speeds will enable single-point tungsten carbide tools to be more widely employed and the danger of breakage due to over-running on the thread seems to have been eliminated. The larger type of lathe, capable of sustaining a heavy cut in steel, will give full effect to the device."

The inventor, Mr. B. J. Farrow, of Wimborne St., Cranborne, Wimborne, Dorset, has filed applications for patents in Great Britain and all other major manufacturing countries. Smart & Brown (Machine Tools) Ltd., of Sabel Works, Biggleswade, are proposing to incorporate the device in some of their new designs.

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CLASSIFIED ABSTRACTS

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AERODYNAMICS

Analysis of the Heat-Insulating Properties of the Laminar Compressible Boundary Layer.

By P. A. LIBBY and A. PALLONE. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 21, No. 12, December 1954, pp. 825-834, 5 illustrations.)

IN some cooling problems associated with high energy flows, it may be convenient to localise strongly the cooling, as, for example, by injecting a coolant through an upstream porous strip and, depending on the insulating properties of the boundary layer, to reduce, or to eliminate completely, the need for further cooling on the surface downstream of the highly cooled section. This upstream cooling technique may be of interest in connection with optical windows in hypersonic wind tunnels, and on radomes, wings, and bodies of high-speed aircraft and missiles.

In this paper a method for investigating the insulating properties of a laminar compressible boundary layer on a two-dimensional surface with zero heat transfer is presented. The physical situation here considered thus corresponds to the case in which the heat transfer downstream of the strongly cooled section is completely eliminated. Of practical concern is how the temperature of the uncooled surface varies in the downstream direction from its low initial value and thus how the low energy layer established by the upstream cooling insulates the downstream surface.

The Kármán integral method, extended to both the momentum and energy partial differential equations of the boundary layer, has been used. The station at which cooling and/or injection ceases corresponds to a discontinuity in boundary conditions and hence in solutions. At this point, the flux of mass, momentum, and energy within the boundary layer has been made continuous by the introduction of three additional parameters in the velocity and stagnation enthalpy profiles. Thus, these profiles have both been taken as sixth-degree polynomials. The resulting two integral-differential equations are then solved for two unknown functions of the distance along the wall. These two functions are related to the boundary-layer thickness and to the wall temperature. Initial conditions corresponding to a given initial wall temperature and an initial boundary-layer thickness are prescribed. Exact closed-form solutions for the case of zero axial pressure gradient are obtained. For flows with significant pressure gradients, numerical solutions are required in general. Several numerical examples of practical interest are presented.

BEARINGS

Scoring Characteristics of Bearing Metals.

By A. E. ROACH. (From *Product Engineering, U.S.A.*, Vol. 25, No. 11, November 1954, pp. 171-175, 5 illustrations.)

SELECTION of materials with suitable non-welding characteristics has become more challenging with the widespread adoption of heavier loads, faster speeds, and higher temperatures, particularly when coupled with the reduced flow rates of low-viscosity oils. Of the 92 naturally occurring elements, there are only 37 of the metals, ranging from beryllium to uranium, which are at all practical for consideration as bearing materials. The non-metal, carbon, can be added to this list because of its many bearing uses in the form of graphite.

To determine the relative merits of these 38 materials with regard to their resistance to scoring, each was run under partially lubricated conditions with one particular steel as a control. Samples were tested in the form of slider bearings, measuring $\frac{5}{8} \times \frac{5}{8}$ in. and run in contact with a rotating steel disc. The angle of convergence between test bearing and disc was 0·5 deg. Disc speed was 5400 rpm, and the average sliding velocity 4640 ft per minute. Lubrication was provided by a stream of kerosene directed on the hub of the disc at a flow rate of about 10 cu in. per min. Electrical resistance measurements across the kerosene film showed that metal-to-metal contact occurred at all loads, indicating that, at best, lubrication was only partial.

Experience has shown that the best bearing metals will score and gall when the operating conditions are sufficiently severe. Hence, the designer's first concern in designing sliding parts should be to make the operating conditions as favourable as possible. The ideal operating condition is to have a fully pressurised circulating oil system. However, with such a system, provision must be made for handling quantities of oil. This involves the complication and expense of oil reservoirs, pumps, plumbing, slingers, seals, and related components, and sometimes leads to dangerous over-simplification in the selection of components of oiling systems. Even with good lubrication, metal-to-metal contact may occur during starting and stopping, when carrying momentary overloads, and at other critical times.

Although the tests were carried out with " elemental " metals, the results are applicable to many materials which are commercially important as bearing materials. Such materials are of three types, i.e., elemental metals, mixtures of metals, and solutions of metals.

The examples described in this article show how the score-resistance ratings of elemental metals, when properly interpreted, can be applied to the more complex materials used in commercial bearings.

CORROSION

Corrosion of Nickel Cast Irons in Soils.

(From *National Bureau of Standards Technical News Bulletin, U.S.A.*, Vol. 38, No. 11, November 1954, pp. 160-161, 1 illustration.)

A LONG-RANGE study of the corrosion of nickel cast irons in soils has recently been completed by the National Bureau of Standards. From measurements on pipe specimens after exposure to different soil conditions for periods up to 11 years, it has been possible to evaluate the effect of varying amounts of nickel in the castings.

Corrosion of cast iron in soils is characterised by the development of an adherent layer of corrosion products which increase in thickness as corrosion progresses. The thickening of this layer is due, in part, to electrochemical action between the ferritic and graphitic constituents of cast iron and partly to differences in potential arising from contact of the metal with the soil. In cast iron exposed to the air, addition of nickel or of nickel plus chromium to the casting has been found to give improved corrosion resistance by reducing galvanic action within the metal itself. To determine the effect of such additions on the corrosion of cast iron in soils, the Bureau included samples of nickel cast irons in an ex-

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tensive series of exposure tests of materials for underground construction. With the completion of this work, data have become available for exposure up to a maximum of 11 years for specimens of low-alloy cast iron, and up to a maximum of 14 years for specimens of high-alloy cast iron.

In the low-alloy cast irons, additions of nickel up to 3% were found to reduce initial corrosion in poorly drained soils of low resistivity, but this advantage was not maintained for the duration of the tests. Thus, the weight losses of the low-alloy cast irons exposed for the maximum period did not differ greatly from the losses of the plain cast iron. Hence, it would appear that the rates of corrosion of the alloys containing as high as 3% nickel decrease less with time than do the rates for plain cast iron and the alloys containing smaller amounts of nickel.

Measurements of hydraulic bursting pressure were also made on samples of the nickel cast irons after exposure to different soil conditions. Because the original shape and appearance of the metal are retained, visual observation gives no indication of the extent of corrosion in cast iron which has been buried. It is generally recognised that corroded cast iron retains some of its original strength, but the extent to which cast-iron pipe may corrode underground and still retain sufficient strength to withstand the pressures commonly used in water- and gas-distribution systems had not previously been estimated.

Most of the low bursting-strength values obtained probably were not accurate measures of the strength of the corroded pipe at the time of its removal from the soil, since these low values may have resulted from oxidation of the corrosion products during storage or from damage to the pipe in handling and shipment. The partial results of incomplete field tests of the bursting pressure of undisturbed sections of plain cast-iron pipe are in good agreement with the measurements made on the stored samples.

Inhibitor Evaluation by the Pearson Null Bridge.

By B. L. Cross and N. Hackerman. (From *Corrosion, U.S.A.*, Vol. 10, No. 11, November 1954, pp. 407-412, 10 illustrations.)

Good rapid methods for evaluating corrosion inhibitors are not yet available. In systems where the electromechanisms of corrosion may be presumed to operate, it has been customary to measure the change in some electrical property of the system as a result of inhibitive addition. Usually, change in corrosion potential has been the criterion; however, this quantity alone is insufficient. Ideally, measurement of a change in local cell current or the full self-polarisation diagram is needed. Methods of obtaining such quantities are difficult or are restricted to a few special systems.

Pearson considered that changes taking place at local electrodes of a corrosion couple were largely explainable in terms of resistance changes, and devised a system for measuring such changes. His bridge is capable of obtaining anode and cathode polarisation curves with applied current, as well as "film resistances" at each electrode.

If the principal effect of inhibitors is to provide a barrier at the metal surface and if the barrier interferes with current flow, then the net result is introduction of an ohmic resistance. The Pearson null bridge is suitable for measuring such resistance changes as may occur, particularly since it is capable of determining these values separately for anodes and cathodes.

Although the bridge was already being studied elsewhere for the purpose indicated above, it was decided to carry on this investigation because of the procedure's potential usefulness. Accordingly, a Pearson null bridge was built, in order to determine its usefulness in the evaluation of corrosion inhibitors. Eight compounds and three commercial inhibitors were tested, using steel in aqueous sodium sulphate solution as the corrosion system. The materials used had all been studied by various other means, thereby permitting comparison of previous results with those obtained by this method. As an estimate, this procedure gave about 70% correlation with other methods, insofar as inhibiting mechanisms are concerned. This is on the basis of qualitative classification only. As a quantitative tool, the bridge in its present form appears to be considerably less useful.

GEARS

Stoeckicht Epicyclic Gearing.

By H. Barwig. (From *Konstruktion, Germany*, Vol. 6, No. 10, October 1954, pp. 377-384, 19 illustrations.)

The capacity of gears is limited by speed and specific tooth loads. Within these limits planetary gears are more efficient than ordinary spur gears and for equal power have the advantages of a considerable saving in space and weight, coaxial driving and driven shafts, and absence of reaction forces exerted on the gear case. Stoeckicht epicyclic gearing has all these advantages and is finding increasing application in large reduction gears coupled to steam or gas turbines of stationary or marine power plants, as well as in the drives for rotary compressors.

Recent improvements are the adoption of the double helical tooth form, with a tooth profile which deviates from the standard and which reduces specific tooth

(*Continued overleaf*)

AIR-BUBBLE CURTAIN FOR CUSHIONING BLASTING OPERATIONS.

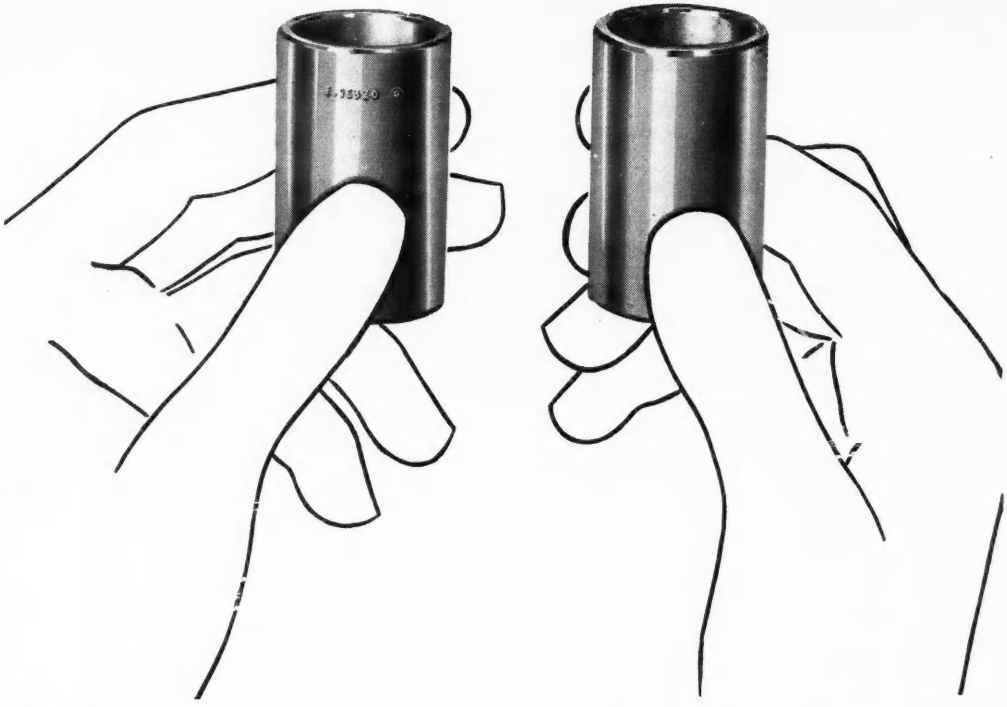
(*Concluded from page* 10)

The use of sand, which is usual for such barriers, was not feasible with the air curtain. Air flow from buried pipes would displace the sand, while pipes laid on the sand would allow the shock waves to pass below the pipe. Experience has revealed that water-filled sand or broken rock transmits hydraulic shock almost as well as water alone.

Two possible modes of action of the air bubbles are suggested. Because the air bubbles differ radically from the water in density and modulus of compressibility, they can act as reflectors and can scatter the energy in the pressure waves. Such dispersion, however, is dependent on the cross-section of the scattering particles ; in this instance, the diameter of the air bubbles is a very small fraction (1/30 to 1/100) of the wavelength of the pressure waves. Consequently, the attenuation by scattering of the energy is not considered to be great.

The compression of the air bubbles by the shock wave appears to be a more significant effect. When air is compressed, the work expended appears as heat. Compression of a sample of air at 15° C to one-twentieth of its initial volume will raise its temperature to nearly 500° C, if no heat is allowed to escape. Although the pressure pulse lasts only about 1/1000 sec, the compressed bubbles, which are flattened rather than spherical, have a very favourable surface-to-volume ratio. This factor, together with the probably violent turbulence of the air within the bubble, is likely to result in an appreciable transfer of heat to the water. The heat thus lost will not then be available to re-expand the bubble sufficiently to pass the pressure waves along.

The studies and applications described have confirmed that water-borne pressure waves can be effectively reduced by means of an air-bubble curtain. Data recorded of the blasts at Niagara indicate that large explosive charges can be detonated in close proximity to structures without causing any measurable damage. It is expected that the method will find extensive use in the future.



What's the difference between these two bearing bushes?

Bush No. 1 is a Glacier Standard Bronze Bush—No. E.16320 ; Bore 1 inch, length 2 inches, outside diameter $1\frac{1}{4}$", available at a moment's notice. Bush No. 2 is non-standard. Bore 1 inch, length 2 inches, *but outside diameter* $1\frac{9}{32}$". Some hundreds were made specially for one customer. That $\frac{1}{32}$" difference on the diameter was probably unimportant, and it delayed delivery. Had the designer chosen to use Standard Bushes, they could have been supplied the next day—and at less cost. If the job needs a special we *can* make it—but it pays to check first, because we make millions of *standard* bearings every year for an enormous number of engineering applications :

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pressure. All the gears are generated, and the sun and planetary gears are shaved and nitrided; finally, the assembly is lapped. In order to minimise the effect of machining errors, the central gears are supported elastically and torque is transmitted to the shaft or case by toothed couplings. Inertia forces due to machining errors in double helical gears cause a temporarily asymmetric transmission of the loads on the two halves of the double helix; this disadvantage is overcome by the arrangement of two independent single helical outside gears, elastically connected with each other by an additional toothed coupling. For high speeds and for more than three planetary gears, the elastic suspension alone does not overcome all inertia troubles, and a radially flexible design of the outside gear, which carries a relatively smaller load, then contributes materially to quiet running, efficient power transmission, and to a considerable reduction in dynamic tooth loads.

Examples of Stoeckicht epicyclic gears in service include a reduction gear transmitting 10,000 hp at 5500/3000 rpm in the steam-turbine power plant of a coal mine, an accelerating gear increasing the 1500 rpm of a 2600-hp electric motor to 9470 rpm for a rotary compressor, a marine reduction gear for 650 hp at 16500/500 rpm, and a gas-turbine drive of 1000 kW at 6750/1500 rpm. The projected design of a reversing ship's gear for 10,000 hp at 110 rpm, with a reduction ratio of 4·35 to 1 in forward and reverse, is also described in detail in this article.

MAGNETISM

A New Automatic Hysteresis Curve Recorder.

By F. G. BROCKMAN and W. G. STENECK. (From *Philips Technical Review, Holland*, Vol. 16, No. 3, September 1954, pp. 79-87, 9 illustrations.)

THE various curves which relate the magnetic induction B (or alternatively the magnetisation $\mathfrak{J}$), to the field strength H in ferromagnetic materials (hysteresis loops, initial magnetisation curves, minor loops) contain data of practical as well as of theoretical value. Determinations of these data are therefore of considerable importance. More often than not, the determination of at least one and frequently of both quantities B and H is accomplished by measuring the electromotive force produced in a coil of wire by a change in the magnetic flux.

The equipment described in this article serves for the automatic tracing of hysteresis curves. As usual, B and H are measured by the integration of the electromotive forces which are generated in suitably placed coils when the field is changed. The instrument contains two identical integrators, one for B and the other for H, providing output voltages which are the time integrals of their input voltages. These output voltages respectively operate the movements of the paper and the pen of a self-balancing X-Y recorder, so that B is plotted automatically as a function of H. The integrators make use of the fact that the voltage across a capacitor is proportional to the time integral of the current flowing into it. The simple RC-integrating circuit, consisting of a capacitor, connected *via* a resistor to the e.m.f. to be integrated, has the disadvantage that it can be used only when the integration time is short compared with the value of RC. For practical reasons the value of RC is restricted, so that, for integration periods longer than about 1/50 sec, the simple RC-circuit is not suitable. The integrators actually used avoid this difficulty and may be used for the integration times of one or two minutes which occur in practice when investigating non-laminated samples or samples with high coercivity.

The accuracy of the curves obtained is usually better than 0·5%. The scales along the B and the H axes can be set at convenient values at the beginning of the measurement. It is also possible to obtain directly the magnetisation, instead of the induction, as a function of H. One of the features of the equipment is the employment of a novel input device, making it possible to plot this magnetisation, while maintaining free and independent choice of the scales along both axes. The same device permits automatic correction for the wire size of the B coil.

Permanent Magnets.

By F. NUÑEZ and S. VELAYOS. (From *Revista de Ciencia Aplicada, Spain*, Vol. 8, No. 5, September-October, 1954, pp. 385-392, 12 illustrations.)

PERMANENT magnets, which are used to produce magnetic fields of constant intensity, have been satisfactorily employed for many years in a large number of applications. To-day, marked improvements in their construction have been made and permanent magnets capable of storing very high magnetic energy are now being produced, thereby opening up new fields of application, reducing costs, and increasing the efficiency of the apparatus in which they are used.

This article describes the relations which must be considered in the design of permanent magnets, and applies these relations, on the basis of data deduced from experimentally determined demagnetisation curves, to two materials of very different characteristics used in their construction, these being a cobalt steel and an Alnico alloy. In this connection, while it is true that there are many factors which must be considered in the design and manufacture of a magnet intended for a specific service, the most important are undoubtedly coercivity and remanence, both of which are characteristics of the material used for construction.

In addition, the article describes a number of experiments relating to the stability of magnets, and concludes with a consideration of the substitution of the demagnetisation curve by one branch of a hyperbola. It is pointed out that, while such a substitution is commonly referred to in the literature and is valid enough for most materials generally used in the construction of permanent magnets, measurements by the authors have shown that it does not apply in the case of some of the new materials now being used.

THERMODYNAMICS

An Analysis of Turbulent Free-Convection Heat Transfer.

By F. J. BAYLEY. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, December 1954, 10 pages, 4 illustrations.)

THE need which has arisen in recent years for effective means of cooling the rotating blades of internal-combustion turbines has been largely responsible for the development of a renewed interest in heat transfer by natural convection. This mode of heat transfer, which depends upon motion created by buoyancy forces in a heated or a cooled fluid, is ideally suited for use in turbine rotor blades, in which the inevitably large centrifugal accelerations often cause these forces to be thousands of times larger than they would be under otherwise comparable gravitational conditions. However, it is for this reason also that there are relatively few data available for the calculation of free-convection heat-transfer rates in rotating machinery, since the large buoyancy forces present lead to fluid velocities which are generally sufficiently great to cause turbulent flow conditions.

The research programme, of which the work described in this paper forms a part, is concerned primarily with an investigation of methods of cooling gas-turbine rotor blades by the evaporation of liquids enclosed within them. It has been found, however, that free convection data, involving no change of phase, have provided a useful basis on which to correlate experimental results. The theoretical work described in this paper was undertaken, therefore, to enable the comparison between natural convection and evaporative

PROGRESS IN ELECTRONICS

The wonder of television is already lost to the millions who see and hear in their own homes events which may be occurring hundreds of miles away. It is already an accepted part of our lives, to be judged and debated not on its technical qualities, but on its value as an entertainment and its influence on our culture.

And yet what it is and what it may become depends largely upon the scientific research and manufacturing techniques that have converted light into electrical energy, and electrical energy into light.

Present day television would be impossible without the cathode ray tube. A beam of electrons, modulated by received signals, scans a fluorescent screen within the tube, and paints upon it a reproduction of the original scene or picture.

Mullard long-life cathode ray tubes are specially designed to maintain excellent picture quality over a very long period of service. Modern methods of production and rigid quality control permit large scale manufacture of tubes of consistently high performance, even though they are highly intricate and complex devices.

Mullard's contribution to the development of television is, therefore, a significant one. Great manufacturing resources are supported by extensive research and development facilities, and these are at the service of an industry which leads the world in the progress of electronics.

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heat transfer to be extended into the range of variables relevant to gas-turbine rotor-blade cooling. A theory of turbulent free-convection heat transfer is developed and is applicable to liquid metals and to some other fluids having more conventional properties.

The main conclusions to be drawn from this paper are that, for Prandtl numbers near unity, a simple power law relates the Nusselt and Grashof numbers from the threshold of turbulence to beyond the range of Grashof number likely to occur in any practical problem, and that the constants in this law may be adequately determined from tests undertaken conveniently at the lower end of the scale. For fluids of low Prandtl number in general, and mercury in particular, the local Nusselt numbers vary less rapidly with Grashof number and are lower than for the corresponding conditions in the previous case. Again, it is shown that large errors will not be incurred by extrapolating data obtained at lower Grashof numbers into the turbine operating range. There is a real need for experimental data with which to compare the theoretically predicted heat-transfer rates for liquid metals obtained in this paper, especially in view of the potential importance of these fluids, not only as coolants for gas-turbine rotor blades, but also because of the properties which make them particularly suitable for extracting heat from nuclear-energy sources.

WELDING

Flash-Welding Aluminium to Copper Tubing.

By W. F. Haessly. (From *The Welding Journal, U.S.A.*, Vol. 33, No. 12, December 1954, pp. 1162-1170, 20 illustrations.)

The most common application for the flash-welding of aluminium to copper tubing is in the refrigeration industry, where it is often desirable to terminate aluminium tubing with a short length of copper tubing. It is necessary that the joint must withstand mechanical abuse when imposed directly on the weld and still be pressure-tight to refrigerant gases. These requirements must be fulfilled when the weld area is reduced to that of the parent material.

An accepted phenomenon is that a brittle alloy is formed when these two metals are united by flash butt welding, and variations in this brittle zone are obtained through application of the proper welding technique with equipment developed to apply it.

Copper and aluminium have extremely narrow plastic ranges, so that slight variations in the degree of heating will readily cause considerable variations in the extent of plasticity. Any variations in plasticity will readily affect the forging force applied to the weld when upset pressure is applied at a predetermined amount for a fixed distance. This in turn causes variations in thickness of the alloy formation, contributing to joint inconsistency when judged accordingly by ductility and impact characteristics.

This paper concerns the practicability of using flash-welding for joining copper to aluminium tubing on a production basis, where weld quality must fulfil the most stringent requirements. It is only in recent years that the welding technique has been recognised for mass production, because of the ability to control consistency. Basic welding procedure is outlined and weld schedules are given for two common material sizes, where pinch-off dies were used to strip off the external upset metal. Successful welding equipment is discussed, with emphasis on those factors which are mainly credited for controlling consistency.

Photomacrographs are included, to illustrate the use of metallographic examination for selecting optimum machine settings, as well as destructive and proof test procedure suitable for production control.

Improved Semi-Automatic Welding and Hard Facing.

By H. S. Avery, T. G. Brashear, Jr., H. J. Chapin, and G. H. Edmunds. (From *The Welding Journal, U.S.A.*, Vol. 33, No. 11, November 1954, pp. 1073-1079, 5 illustrations.)

Ever since the use of covered electrodes became established, the intermittent nature and the high labour costs of manual arc welding have been matters of concern. This logically led to the development of automatic welding, which depended for its success upon protection of the molten weld metal by a blanket of granular flux, by a shield of inert gas, or by inclusion of deoxidising elements in the electrode. These three procedures are industrially important to-day and adaptations to hand- or semi-automatic welding have been made. However, further improvements in cost or convenience are desirable.

Manual semi-automatic welding under a flux blanket has some of the advantages of fully automatic operation in speed and high deposition rates, but concealment of the arc is a common disadvantage. This limits the precision with which the weld deposit can be placed without jigs and fixtures. Furthermore, the handling of the granular blanketing flux is a nuisance and is expensive. With good practice the amount of flux used may be perhaps twice the weight of wire consumed. To the cost of wire and flux must be added the labour involved in clean-up and salvage of the infused granules and sometimes of reclaiming the fused flux by grinding.

This paper describes a new device which combines the advantages of automatic welding with the visibility and flexibility of manual welding. Electrode wire from coils is fed continuously, reaching the arc with a flux covering that can provide arc shielding, de-oxidation, arc stabilisation, slag coverage of the molten bead, and alloying, if necessary. The operator can weld steadily for fifteen minutes, if desired; delay in replacing electrodes and the waste of stub ends are eliminated, and concealment of the arc is avoided.

The range of available welding currents and burn-off rates is wide. An automatic control of arc length makes the device easy to operate. The chief limitation of the device is its adaptability to downhand welding only.

THE INSPECTION AND OVERHAUL OF TURBO-GENERATORS

(*Concluded from page* 9)

An investigation relating to some hundreds of turbo-generators and covering the period from 1948 to 1952 showed (Table I) that, in the steam section, rotating blades were by far the most liable to defect, 32·6% and 22% of the totals having been detected during overhauls and in the course of operation respectively. Bearings came second, with 15·2% and 8·1%, while valves and control gear were last with 3·1% and 3·7%, though here the cost of repairs was high, compared with the percentage of incidence. In the electrical section, rotor defects lead, both as regards incidence and cost of repairs. In condensers, the tubes accounted for the highest percentage of defects, though no conclusions of general validity could be drawn from the figures, because the behaviour of tubes depends very largely on local water-supply conditions. Finally, oil-supply systems also had a substantial share in defect incidence.

The investigation demonstrated that defects were inevitable in the operation of turbo-generators, and though the figures given seem rather high, it must be remembered that they relate to installations produced during a period of development, with a tendency towards larger installations and higher pressures and temperatures, so that, were it not for the preventive measures practised in past decades, these figures would be far less favourable.

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PHILIPS TYPE ES 1382

- ★ A clearly visible calibration scale
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- ★ Ample cooling without oil
- ★ Light in weight
- ★ Robustly constructed in drip-proof sheet-metal housing of pleasing design

This plant, with a generous output range, is ideally suitable for general light, medium and heavy fabrications. It is equally good for all classes of maintenance and repair work.

Capacity is 60 to 350 amps, with infinitely variable current adjustment.

Electrodes 12 s.w.g. to 5/16 in.

The plant embodies the finest modern features of welding transformer construction.

Power Factor Correction

Power factor Correction Capacitors can be fitted if required (A 6KVA capacitor is the appropriate size for this equipment).

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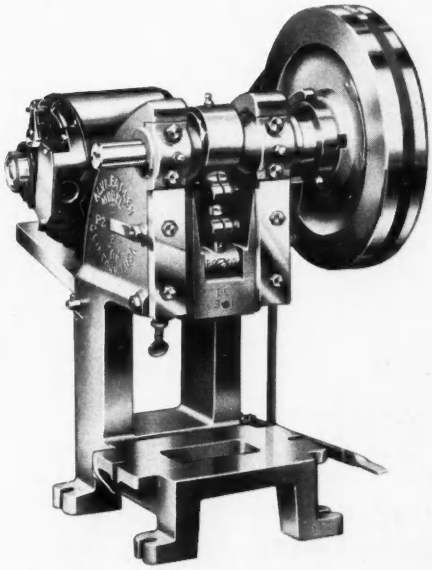
New Materials, Processes and Equipment

BENCH-TYPE PUNCH PRESS

The rugged, precision construction of the new model B-2, 2-ton bench-type punch press developed by Alva F. Allen, of Clinton, Missouri, makes it ideal for the production of small stampings and for assembly or secondary operations.

The press features a quick-action, single-pin clutch with simple, positive, repeat or non-repeat action. Exclusive, straight ram guides, with a flat gib for accurate fitting of dies for precision stamping, are provided. The ram has an accurate adjustment, with a simple, positive lock, and there is extra-large die space for stamping, forming, drawing, riveting, blanking, etc. of metal, plastics, textiles, fibre, leather, paper, etc.

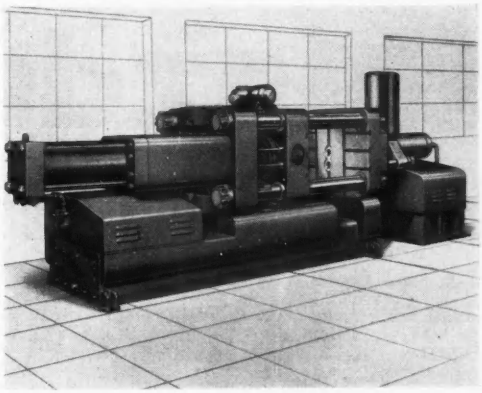


The new press has a capacity of up to 200 operations per minute on continuous operation, has a $\frac{3}{4}$-in. stroke, and weighs only 105 lb. Operation is by a $\frac{1}{3}$-hp motor, *via* a direct V-belt drive.

HIGH-PRESSURE DIE-CASTING MACHINE

A line of radically new cold-chamber, high-pressure die-casting machines, intended to fulfil a definite need for die-casting equipment to parallel technological advances in non-ferrous metallurgy and in the die-casting process, has been designed and built by The Hydraulic Press Manufacturing Company, of Mount Gilead, Ohio.

The new machine features an entirely new clamp design and new advanced-design injection ends. The new clamp offers a combination of hydraulics for smooth, precisely controlled movements and transmission of energy with a simple mechanical linkage and wedge for multiplication of power, resulting in the storage of potential energy. Maintenance of the clamp is virtually nil because there are no toggle pins to shear, no single-line bearing contacts, and no highly stressed members under heavy loads. Automatic lubrication, using molybdenum disulphide lubricants, resists friction over large contact areas.

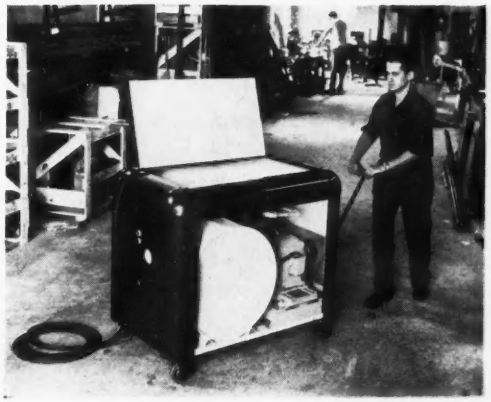


The new injection end is a compact, self-contained unit, including pump, motor, and reservoir, and has been designed to reduce line breaks or leaks inherent in die-casting injection ends because of high speeds and pressures. The new injection end features a special speed-control operating valve which provides variable acceleration and speed control to metal plunger action. Other advantages include ease of positioning, accessibility for servicing, constant and positive plunger movement, and maximum required speeds for all die-casting alloys, including aluminium and magnesium. All high-pressure hydraulics are manifolded for compactness, elimination of line breaks, and consequently greater safety.

MOBILE VACUUM PUMP

A radically new machine, described as the first and only mobile vacuum-pump unit now available, has been developed by the Vacuum Forming Corp., of Port Washington, N.Y.

Designated the " VacForm " Mobile Pump Wagon, the unit is housed in a protective metal cabinet with removable panels, mounted on a heavy steel frame, with a convenient swing-back top-door opening, and rubber-



Mazda

High-Bay Fitting

This Mazda high-bay tungsten lighting fitting can be used either alone or mounted on a control box with one or two mercury vapour components to form a Mazda Blended Light Unit. Convected airflow minimises dust accumulation inside the reflector and does away with the need for a cover-glass. Only occasional cleaning is necessary.

SPECIFICATION

Spun aluminium *overlamp* concentrating reflector, electrolytically brightened and anodised. Simple pre-focusing adjustment for appropriate lamps, with panel indicator. Convected airflow vents. Cool wiring. Funnel finished in vitreous grey enamel. Conduit suspension $\frac{3}{4}''$ tapped. Approximate weight (complete) : 7 lb.

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The Mazda C84816 Industrial High-Bay Fitting with anodised aluminium Reflector for use with one 500 W, 750 W, 1000 W or 1500 W G.L.S. Lamp.

Exploded view of funnel showing focusing adjustment and the method used to ensure cool wiring.

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tyred, ball-bearing wheels on swivel casters for effortless trundling.

When the unit is pushed into place, it is connected by a heavy-duty hose to whatever equipment is to be used in the vacuum application, e.g., presses, concentrators, driers, and moulding units. Adaptable to varying electrical requirements, it is then plugged into an ordinary electrical connection and is ready for action. An added feature making for ease of operation is a system of start-and-stop push-button controls.

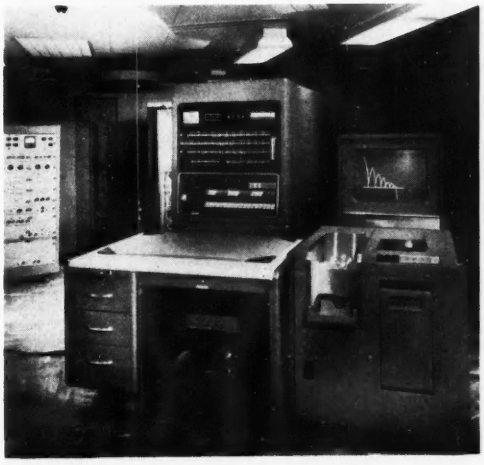
The unit, which weighs 900 lb, is 3½ ft high, and requires only 4 ft by 2½ ft of floor space, includes an air-cooled rotary pump with automatic lubrication, a vacuum gauge, and an adjustable vacuum shut-off switch. The amount of vacuum to be created can be easily controlled, with a potential up to 29½ in. at sea-level. The 50-gallon welded surge tank provided has a bottom drain. Other features for convenience and safety include thermal overload protection for the 3-hp motor and an exhaust filter which eliminates the necessity for either an indoor or outdoor vent.

CATHODE-RAY TUBE OUTPUT RECORDER

A new device, announced by International Business Machines Corporation, of New York, is their Type-740 Cathode-Ray Tube Output Recorder, designed for use with their Type-701 and 704 electronic data-processing machines.

Potential uses of the visual display afforded by the new machine are almost unlimited. For example, as the shape of a cam is computed by the electronic "brain," the shape, as well as successive positions of the cam, can be displayed on the cathode-ray tubes, inspected, and photographed at high speed. In production management, the machine can display graphs showing schedules of traffic or machine-shop loadings being computed by the electronic data-processing machine. Study of the visual data on the face of the cathode-ray tube would thus aid in determining the best procedure. It could be extremely useful in simulation applications for both military and civilian use. For example, if an aircraft were picked up on radar equipment, its speed, position, and heading could be determined by a large computer and the track of the aircraft flashed on the screen of the cathode-ray tube. In civilian use, the device could be applied to the control of air traffic within radar range of large airports.

The device records computed data points on two cathode-ray tube faces at the rate of 8000 per second. The time consumed in displaying a point is approximately 125 microseconds. The use of the computer is required only during transfer of information to the recorder, after which the calculator is free to continue its computing while the data within the output recorder are automatically processed.



The machine consists of a display unit and a recording unit. The display unit features a 21-inch cathode-ray tube which is used for immediate visual display and inspection of the data being computed. The recording unit contains a 7-inch cathode-ray tube. A 35-mm pulse-operated camera may be used with this unit for photographing the data shown on the tube; such data may take the form of graphs, geometrical figures, symbols, words, or numbers. A point shown on the face of the display unit cathode-ray tube lasts for about 20 sec and is accurate to 3·0%. The displays of the smaller tube in the recording unit, which are accurate to 0·1%, last for a few micro-seconds, during which time the camera photographs the information on the face of the tube. By the use of appropriate instructions or programming techniques in the computer, all the cathode-ray tube displays and operations of the camera are completely automatic and under the control of the computer.

NEW MILLING-CUTTER COMBINATION

A new milling cutter combination, consisting of a specially designed cutter body and inserted blades which are carbide-tipped and form-relieved, to reproduce serrations in such items as inserted blades of milling cutters, boring bars, counter bores, spot facers, and reamers, is announced by Fenton Carbide Tool Co., Inc., of Linden, Michigan. The serrated cutting tips of the inserted blades employed in this cutter combination are believed to be one of the first carbide applications for this kind of work, and it is reported that the "Carboloy" grade 78B carbide used to tip the inserted blade requires less regrinding to maintain the serrated teeth in sharp condition.

In production tests during the past three years, the "Carboloy" carbide-tipped blade gave more than three times the production of high-speed steel, enabling the work to be run at table speeds of 20 in. per minute. One of the cutter combinations, during the tests, milled approximately 8000 serrated bodies on one set of blades, and is still in operation after six regrinds, with a stock removal of 0·010 to 0·015 in. per sharpening.

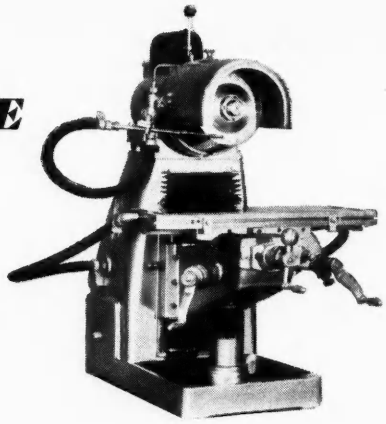
The cutter body is 3½ in. o.d. and 1½ in. in width. The eight inserted blades are mechanically held. The cutter combination is constructed in such a way that blades can be removed and replaced without indicating or grinding in assembly. Furthermore, the same cutter body can be used to make various size and pitch serrations, merely by changing blades. It is stated that this same principle of inserting blades, without indicating or grinding in assembly, can be adapted to carbide form cutters.

HIGH-SPEED LABORATORY MILL

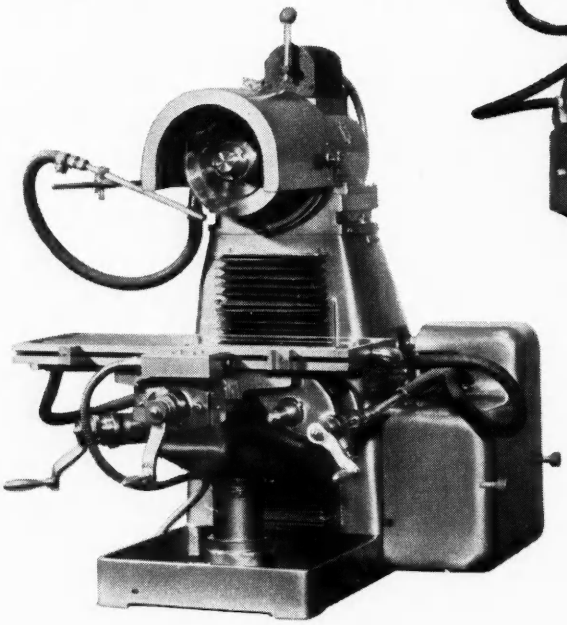
One of the advantages claimed for the new high-speed laboratory mill manufactured by Steele & Cowlishaw, Ltd., of Hanley, Staffs., is that it will grind and disperse materials in at least one-tenth of the time normally taken by an orthodox ball or pebble mill. Furthermore, it will also mill to semi-paste consistency, grind materials wet or dry, and, if necessary, process four different substances simultaneously. Formulations processed in this new mill can be reproduced in bulk production with identical characteristics, the time factor being the only variable.

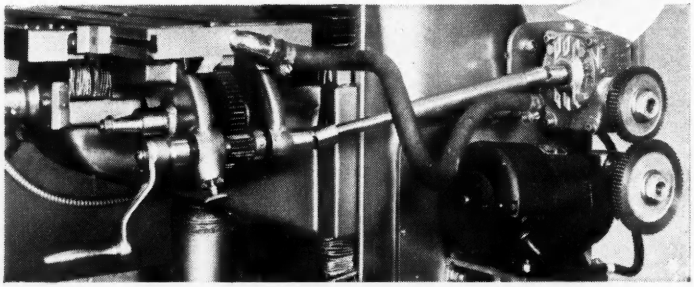
Whilst the mill has a wide range of uses and applications in many branches of industry, it is particularly suitable in the paint industry and the paint manufacturer's laboratory. For example, it will grind and disperse a concentrated charge of colour pigment and medium in approximately 4 hours, a process which normally takes at least 40 hours in an orthodox ball or pebble mill. Alternatively, it will produce a much

CUTTING AND TOOL GRINDING MACHINE



G.F.3 MARK II



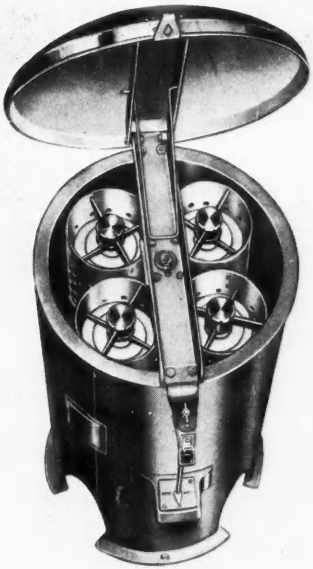


G.F.3 MARK IIa
with automatic traverse

The G.F.3 was introduced originally to satisfy the demand for a small universal machine suitable for use with Neven Diamond Impregnated Tools for chipbreaker grinding and similar tool room work, and certain production operations.

The Mark II model has been developed on the same lines as the original Mark I, but with many improvements, and also a far higher degree of precision. As a result of numerous requests we have now added to our range the Mark IIa model with an automatic traverse; this retains the original simplicity of the Mark II with the addition of a sturdy and compact traversing unit.

IMPREGNATED DIAMOND PRODUCTS LTD · GLOUCESTER



superior dispersion in 5, 6, or 7 hours milling time.

Furthermore, it is stated that materials which previously have proved almost impossible to disperse satisfactorily in orthodox ball mills can be processed rapidly and efficiently in the new mill. In addition, its design is such that the pots are removable and interchangeable and are so positioned that a complete change-over of materials can be carried out in two or three minutes. Standing time is reduced to a minimum by the fact that it is unnecessary to clean the mill between runs, the only delay in production being the substitution of freshly charged spare pots.

The new mill, known as the Steel-Shaw High-Speed Laboratory Mill (Mark I), contains 4 hard-porcelain pots of 5 pints total volume, giving a grinding capacity of 2½ pints of material per pot or a total milling capacity of 10 pints. Overall dimensions are 2 ft diameter × 4 ft 6 in. height.

Also in production is a high-output "Smalls Department" mill (Mark II) which employs the same principles of operation and takes 4 five-gallon pots.

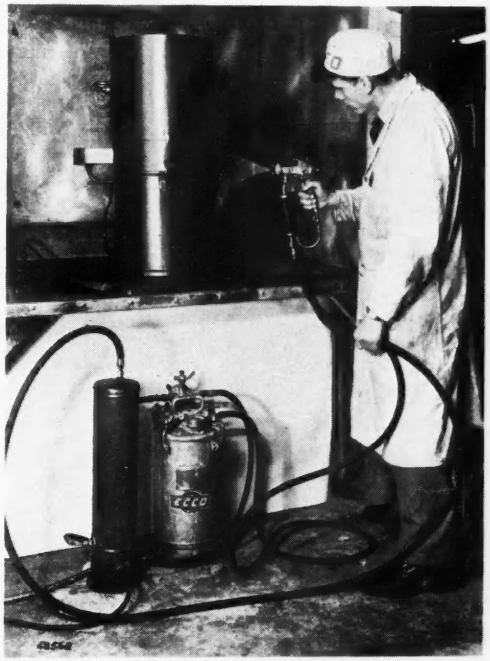
AIR-HEATER AND PAINT PREHEATER EQUIPMENT FOR SPRAYING

Equipment which overcomes "blushing" and "blooming" after spraying cellulose lacquers has been introduced by the ECCO Division of the Atlas Diesel Company, of Wembley. It is an accepted fact that blushing and blooming after spraying cellulose lacquers is due to the deposition, by excessive moisture in the air, of a film on the cellulose surfaces when the temperature of the shop is higher than that of the cellulose film, caused by the chilling effect of the compressed air. To overcome this, Atlas have developed the LE 750 (air heater) and FV 30 (paint preheater), which can be used with ECCO 30 or 303 spray guns, according to the compressor capacity of the shop and the number of guns being used.

One of the problems the painting contractor often has to face is the lack of gloss when working outside under winter temperatures. Another is inadequate coverage by operators—even when using first-class materials. In many cases these faults are caused by over-thinning the materials to enable the spray equipment to work satisfactorily. The new air heater and paint preheater have also been designed to overcome these difficulties.

The LE 750 air heater is a solid, heavily insulated and explosive-proof electric heater (750 W), into which the air from the compressor is passed at the bottom and emerges at the top at thermostatically controlled temperatures ranging from 86 to 190° F. The air then passes through a standard 12-ft length of air hose to the air inlet of the FV 30 preheater, which consists of a honeycombed air coil of compact design. The lacquer/paint fluid hose from the pressure container is connected to the bottom of the preheater and passes up a straight passageway to the fluid inlet at the gun itself. The air outlet of the preheater is connected to the air inlet of the spray gun and is equipped with a bleeder valve, which allows air to pass when the gun is not in use, thus keeping the preheater itself warm.

Tests have shown that, with the thermostat fully advanced, the air temperature at the gun nozzle is between 160 and 170° F. The lacquer/paint temperature, after circulation through the preheater alone, is 90° F. After atomisation at a point 3 or 4 in. from the gun nozzle, it is 110° F. Under the most adverse conditions, the viscosity of the lacquer or paint can be sufficiently reduced by the heater to permit spraying at a temperature equal to and above the normal spraying temperature of 75° F.

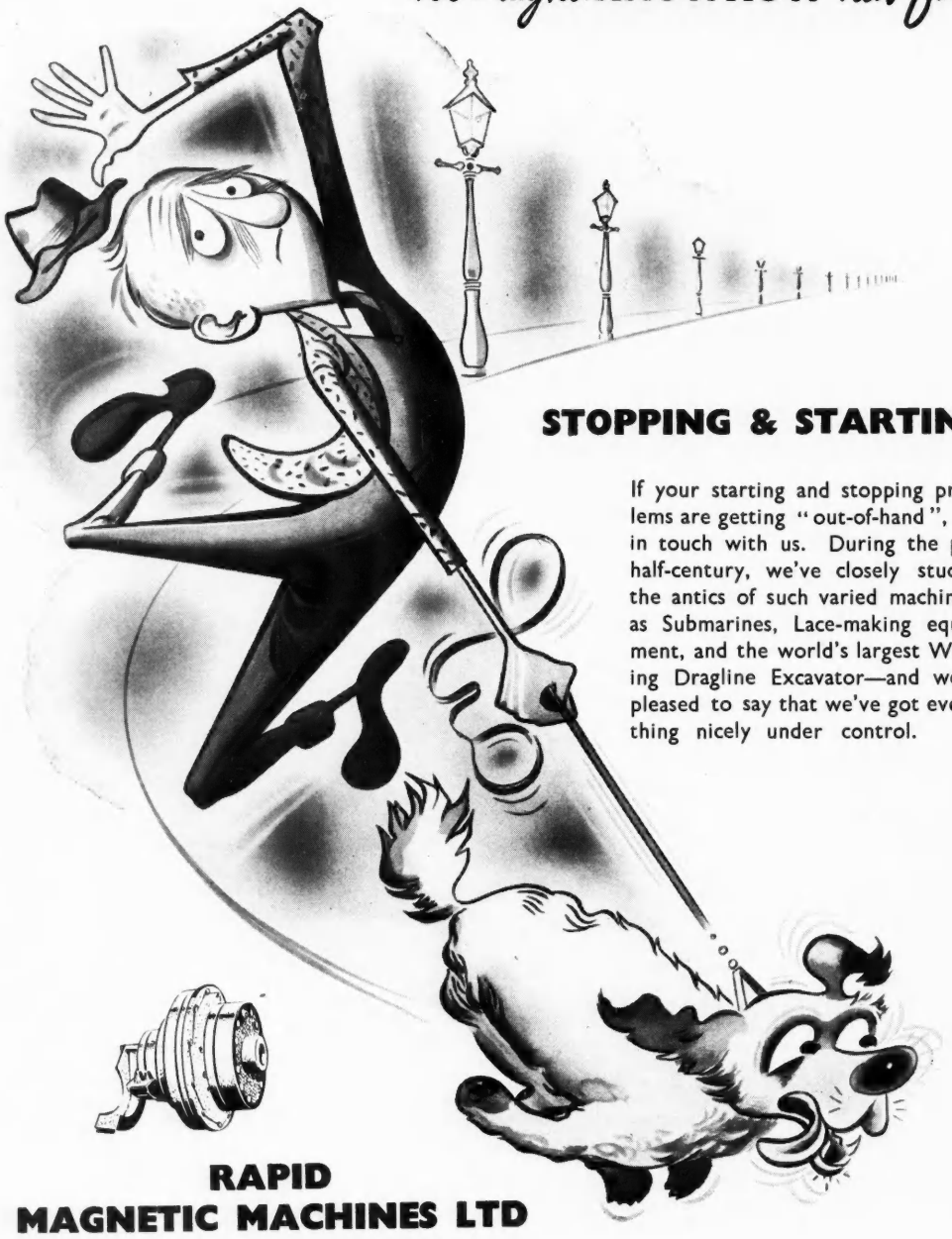


The illustration shows the new paint preheater unit, attached just below the gun. The air heater can be seen at the left of the illustration.

D.C. VOLTAGE STABILISER

Stated to be the first purely electronic voltage stabiliser of such high current rating commercially available as a standard production instrument, the "Servomex" 2·5A, d.c. voltage stabiliser, type 38, manufactured by Servomex Controls Limited, of Crowborough Hill, Jarvis Brook, Sussex, is suitable for scientific and engineering work in a very wide range of fields where a stable low-voltage source is required.

*Mr Magna***KNOWHOW** *has fun*



STOPPING & STARTING

If your starting and stopping problems are getting "out-of-hand", get in touch with us. During the past half-century, we've closely studied the antics of such varied machinery as Submarines, Lace-making equipment, and the world's largest Walking Dragline Excavator—and we're pleased to say that we've got everything nicely under control.

RAPID
MAGNETIC MACHINES LTD
BIRMINGHAM, 12, ENGLAND.

HALF A CENTURY OF SPECIALIST EXPERIENCE

Voltage range is 1 to 15 V d.c., with a continuous current rating of from 0 to 2·5A. Voltage drop, when the current is switched on, corresponds to an output resistance of 2 milliohms (2·5A causes a drop not exceeding 5 mV d.c.). A change in mains voltage of $\pm$ 10% causes a variation in output not exceeding $\pm$ 5 mV. Ripple is not more than 3 mV r.m.s. under the worst conditions.

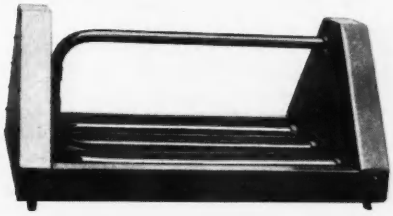
The time of response for full correction of mains changes, or small load-current changes, is about one millisec. For larger changes in load current, the amplifier is overloaded momentarily, and for the worst possible condition, i.e., 2·5A suddenly switched, the time for full correction is about 5 millisec. Mains voltage can vary $\pm$ 10% from the nominal value without any loss of control or overheating. Taps are provided for 200, 210, 220, 230, 240, and 250 V nominal, 50 or 60 cps. The instrument can also be supplied for 100 to 120 V. Two meters are fitted, i.e., an ammeter with a range of 0 to 3A, and a voltmeter with a range of 0 to 3 and 0 to 15 V.

The output terminals need not be earthed, and can be operated at up to 250 V from earth potential. By stabilising the heater voltages, by using wire-wound resistors for the critical points in the circuit, and by extremely careful attention to ventilation, drift has been reduced to an exceptionally low value.

ELECTRONIC TRAMP-METAL DETECTOR

Any material in which the presence of tramp metal is injurious to the end product, or is a hazard to equipment or personnel, can be examined automatically to ensure complete freedom from contamination by means of the MD 9 electronic metal detector manufactured by Metal Detection Ltd., of Birmingham. The tramp metal may be either ferrous or non-ferrous, while the processed material may have a high moisture content or may even be liquid.

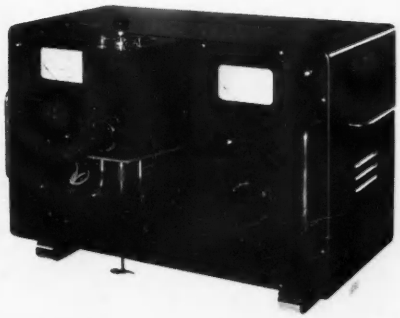
The equipment consists of a search-coil unit and a control unit, together with auxiliary apparatus for the rejection of contaminated material and for alarms. The control unit, which is of standard design for all applications, is ruggedly constructed and is enclosed in a dust-proof case, but is easily accessible for maintenance. The search coil is specifically designed for each installation and consists of two easily separated sections. These can be fitted without cutting and resplicing the belt, thereby reducing lost production time to a minimum. Two basic types of coil are available:—Type HD (illustrated), for use in heavy industry, is designed to withstand the rigorous conditions found in mines, quarries, etc., while type LD is totally enclosed to simplify cleaning in the lighter food- and chemical-processing industries. The material may be fed through the search-coil aperture by a conveyor, chute, pipe, or other materials-handling equipment.



A high-frequency electromagnetic field is set up by the search coil. When a particle of metal passes through the search head, this field is distorted and a signal is induced into a second coil. This signal is passed to the control unit, amplified, and used to operate relays controlling alarms or reject systems. Special circuits are incorporated to minimise the effects of temperature and supply-voltage changes, and these, combined with the inherent stability of the detection system used, practically eliminate adjustment while the equipment is operating. No special skill is required to adjust the apparatus, and routine maintenance is simplified by the use of built-in metering, from which the condition of all valves can readily be determined.

ELECTROLYTIC POLISHER

The disadvantages of the standard method of preparing metallurgical specimens for examination are overcome by electrolytic polishing. However, with the increasing use which is being made of metallurgical techniques, there is a need for a suitable laboratory instrument. The electrolytic polisher developed by Nash and Thompson Ltd., of Tolworth, Surrey, meets this need.



The instrument is housed in a large rectangular box and all the necessary fittings and controls are mounted on the front panel. At the middle of the panel, and towards the top, is the mounting for the electrodes and the stirrer. These are arranged so that they may be lifted (and locked in the raised position), to facilitate the removal of the beaker in which the specimen is polished. The working range of the instrument is 0-70 V, with a maximum current of 5 A. The direct current is smoothed to about 1%. Both amperes and volts are indicated by flush-mounted meters, and control is effected by a

"Give me room!"

gasped the production manager

"I'm being choked," he said. " I'm producing the goods faster than ever, but what's the good? I've got to slow down to enable the stuff to be moved off the floor. I've carried on somehow, but this is the end. Come and look." We did.

His production machinery was tip-top, but oh! — his materials handling equipment was right out of the Ark! " For months now I've been nagging the Board to call in Yale," he moaned, " but they just wouldn't listen."

" Well, now we're here, let's get down to it," we said as gently as we could.

He showed us what wanted moving — how far — and how often. Together we worked out a scheme that did all that and increased his effective storage space more than 25%!

Now he's producing to capacity, his handling costs are less than he had ever hoped and the Yale trucks are giving him the kind of trouble-free service he'd only dreamed about.

We have at your disposal technical staff who will be glad to visit you at any time and demonstrate how Yale products can solve materials handling problems and reduce production costs.

MATERIALS HANDLING EQUIPMENT

Made in England by

YALE

REGISTERED TRADE MARK

THE WORKSAVER This is the Yale " Worksaver ", an extremely compact and manoeuvrable battery-operated truck specially suitable for smaller plants. It is made in five versions — pallet, high-lift platform, low-lift platform, fork-lift and tractor.

For details of the " Worksaver " series, and other materials handling equipment in the Yale range, write or phone:

THE YALE & TOWNE MANUFACTURING COMPANY, MATERIALS HANDLING DIVISION, DEPT. P.1, WEDNESFIELD, STAFFS. WILLENHALL 630

variable auto-transformer. Fine control is provided for the low-voltage ranges. A short-circuiting switch is provided for use in etching the specimen in the polishing solution, as is sometimes required. The stirrer has variable speed control.

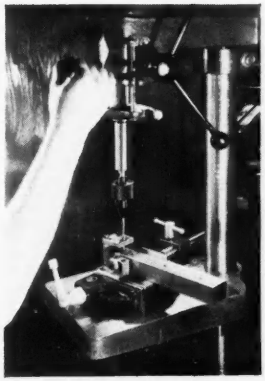
The electrode connections are made to release very quickly, so that the specimen may be rapidly removed for washing at the end of the polishing operation. Cathodes are made of different materials for the different solutions and a range of these is available in copper, aluminium, and stainless steel. A glass cooling coil may also be provided, if required.

The chief advantage claimed for this instrument is its adaptability to a variety of different-sized specimens, and the ease with which different metals can be polished, i.e., merely by changing the beaker and cathode. The largest size of specimen which can be polished is limited to about 3 to 4 cm^2. Edges can be conveniently polished, particularly when mounted in a plastic mould.

SAFETY VISE

A new, instant-change safety vise for rapid set-ups on production pieces has recently been developed by the Wahlstron/Float-Lock Sales Department of the American Machine & Foundry Company, of New York.

The new unit is provided with three bosses for easy jig attachment; any number of holes can be drilled without removing the work, as the vise turns over on three sides for maximum drilling flexibility. The vise locks securely by a quarter turn of a "T" handle at any position on the table, thus making it a dependable drill jig when duplicate pieces are required. The work is tightly locked, or completely released, by simple operation of the hinged handle which operates the screw jaw. When not in use, the vise can be swung completely out of the way.



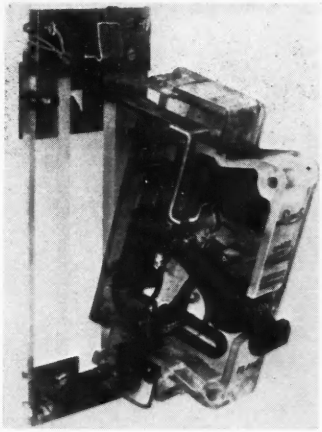
With a choice of either a 9-inch or 12-inch jaw opening, the unit is an excellent holding device for end-drilling and centering, angle drilling, centering long rounds, and for drilling sheet metal.

MINIATURE CIRCUIT-BREAKERS

A new range of "Lupus" miniature circuit-breakers, weighing only 6 oz, has been introduced by the M.C.B. Co. (Manchester) Ltd., of Brooklands, Sale, Manchester.

The design incorporates several novel features, including a self-contained arc chamber, rolling/wiping contacts with integral arcing tips, and a magnetically assisted thermal trip which affords correct protection under all conditions of operation and which is self-compensated for ambient temperature effect. The simple two-member mechanism and the overload protection unit are enclosed in a sealed, completely interference-proof case, the overall dimensions of which are $4\frac{1}{2} \times 1 \times 3$ in. Wiring has been made easy by the provision of universal cable terminals, suitable for front or back connection and for all cable sizes up to 19/·044. Well shrouded fixing holes and terminals are enclosed by self-locking end covers, removed and replaced without tools. Standard ratings of these circuit-breakers are 2·5, 5, 10, 15, and 30 A.

As an alternative to the upper cable terminal, a plug-in contact may be fitted, for bus-bar connection to "Lupus" distribution boxes. This arrangement enables isolation without supply interruption to be made and permits quick substitution of different breakers, all of which are completely interchangeable.



AUTOMATIC-FEED DRAWING PEN

The new "push-button," automatic-feed drawing pen manufactured by the Rule-O-Matic Corporation, of New York, contains an ink cartridge holding the equivalent of 55,000 in. of ruled lines, and should undoubtedly save time and increase production in the drawing office.

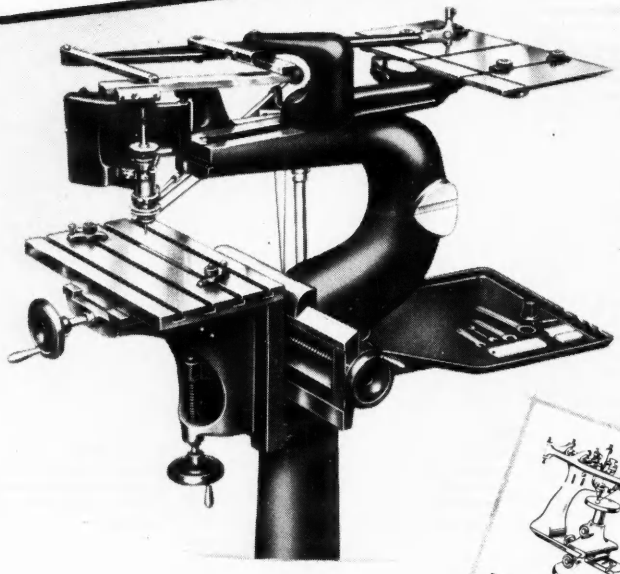
To fill the nib, all that is required is to press the cap. As a result, a concealed feed tube is operated, releasing the exact amount of ink for filling, and eliminating the need for wiping the outside of the nib after filling. Similarly, the new "Rule-O-Matic" pen eliminates the practice of stopping work to fill pens from inkwells, with subsequent drying of the nibs—a process involving wasted motion, ink, and time. The new pens are easily refillable:—The used cartridge, representing about 130 fillings from conventional ink bottles, is removed, the new cartridge is inserted, and the pen is again ready for continuous operation.

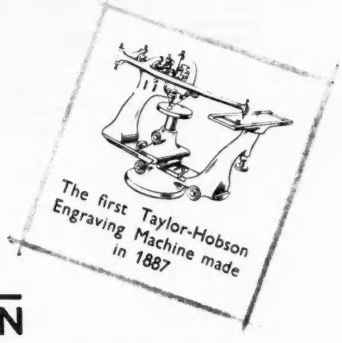
Nibs are of rust-proof stainless steel and are expertly tempered, sharpened, honed, and individually tested to ensure perfect drawing and highest tolerance. The pen is supplied in a neat case, complete with two cartridges.

ERRATUM

It is regretted that on page 488 of our issue for November, 1954, the illustrations accompanying the descriptions of the "Automatic Timer and Cycle Control" and the "Industrial Electronic Relay" were inadvertently interchanged.

FOR OVER SIXTY YEARS





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As leaders in the design and production of Engraving Machines for over 60 years we make a machine with a 'fine' touch which is unsurpassed for versatility and precision.

Particularly suitable for the production of prototype components, engraving, lettering, figures, designs and profile milling.

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NEWS OF THE MONTH

NEW YEAR HONOURS

The New Year Honours List, published on January 1st, includes the following awards to engineers, scientists and industrialists.

BARONS

Edgar Douglas Adrian, O.M., President of the Royal Society, President of the British Association, and Master of Trinity College, Cambridge; and **Sir William Fraser, C.B.E.,** chairman of the Anglo-Iranian Oil Co. Ltd.

KNIGHTS BACHELOR

Ivor R. Cox, D.S.O., managing director, Metropolitan-Vickers Electrical Co., Ltd.; **Wilfred J. Neden, C.B., C.B.E.,** Chief Industrial Commissioner, Ministry of Labour and National Service; **Sydney G. Russell, C.B.E., M.C.,** designer and artist; **Leonard Sinclair,** chairman and managing director, Esso Petroleum Co. Ltd.; **Rear-Admiral Matthew S. Slattery, C.B. (ret'd.),** chairman and managing director, Short Brothers and Harland Ltd., Belfast; **Henry Spurrier,** managing director, Leyland Motors Ltd.

ORDER OF THE BATH

G.C.B. **Sir John P. R. Maud, K.C.B., C.B.E.,** Permanent Secretary, Ministry of Fuel and Power.

K.C.B. **Vice-Admiral (E) Frank T. Mason, C.B.**

C.B. **Rear-Admiral (E) John G. C. Given, C.B.E.; George R. D. Hogg, C.B.E.,** Under-Secretary, Department of Scientific and Industrial Research; William R. McGaw, director general of aircraft production, Ministry of Supply.

ORDER OF SAINT MICHAEL AND SAINT GEORGE

C.M.G. **Edward W. Senior,** commercial director, British Iron and Steel Federation.

QUEEN'S COMMENDATION FOR VALUABLE SERVICE IN THE AIR

Mrs. Anne Burns, principal scientific officer, Royal Aircraft Establishment, Church Crookham, Hampshire.

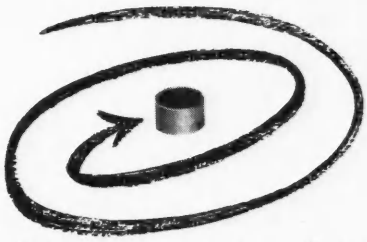
ORDER OF THE BRITISH EMPIRE

K.B.E. **Owen H. Wansbrough-Jones, C.B., O.B.E.,** chief scientist, Ministry of Supply; **Eric A. Seal, C.B.,** deputy secretary, Ministry of Works.

C.B.E. **Risdon A. Beazley,** chairman and managing director, Risdon Beazley, Ltd., Southampton; **John Beaumont, O.B.E., A.F.C.,** Commandant, Technical Training College, Indian Air Force, Jalahalli, India; **David Blee,** chief of commercial services, British Transport Commission; **Charles S. Bryant,** lately director of materials, and explosives research and development, Ministry of Supply; **Lewis Chapman,** managing director, William Jessop and Sons, Ltd., Sheffield; **John C. Clark, M.C.,** Director of the Rural Industries Bureau; **Isaac W. Cumberbatch, O.B.E.,** chairman, West Midlands Division, National Coal Board; **Colonel (temporary) Eric P. Dickson,** Corps of Royal Engineers; **Colonel (temporary) Henry Grattan,** Corps of Royal Engineers; **Frederick W. Halliwell,** President of the Gauge and Tool Makers' Association; **Harold W. Hobbs,** director of ordnance factories, Nottingham, Ministry of Supply; **Frederick J. C. Honey,** secretary, British Employers' Confederation; **Horace E. Jackson,** lately President, British Non-Ferrous Metals Federation; **Neil C. Macnamara,** chairman and managing director, Trollope and Colls Ltd., London; **Cecil T. Melling,** chairman, Eastern Electricity Board; **George Ormiston,** superintendent engineer, New Zealand Shipping Co. Ltd., and Federal Steam Navigation Co. Ltd.; **Alfred H. Parker,** Assistant Director of Dockyards, Admiralty; **Victor A. Patterson, J.P.,** deputy chairman and managing director, J. and E. Hall, Ltd., Dartford; **Professor Charles H. Smith,** Department of Instrument Technology, Royal Military College of Science; **Alfred Watson,** chief mechanical and electrical engineer, Air Ministry; **Major Francis R. B. Whitehouse, M.B.E.,** chairman and managing director, Chad Valley Co. Ltd., Birmingham.

O.B.E. **Harold J. Atkinson,** area general manager, North Eastern Division, National Coal Board; **George W. Bain,** chief engineer, S.S. "Mauretania," Cunard Steamship Co., Ltd.; **Lieutenant-Colonel Herbert H. Broadbent, T.D., R.E.M.E.,** Territorial Army; **Robert Connor,** director and general manager, Measurement, Ltd., Oldham; **Herbert Duckworth,** superintending electrical engineer, Admiralty Engineering Laboratory, West Drayton; **G. D. Elliott,** works manager (iron), Appleby-Frodingham Branch, United Steel Companies Ltd., Sheffield; **Wynn H. Evans,** principal scientific officer, Safety in Mines Research Establishment, Ministry of Fuel and Power; **William J. Felton,** secretary, Institution of Mining and Metallurgy; **Alfred E. Gollop,** assistant director of storage, Ministry of Supply; **A. S. Hartshorn,** principal scientific officer, Royal Aircraft Establishment, Farnborough; **Gerald A. Hill,** director, Higgs and Hill, Ltd., Crown Works, London; **Arthur T. Horton,** principal scientific officer, Ministry of Defence; **Professor Leslie Howarth,** Department of Applied Mathematics, University of Bristol; **Ronald C. Kelt, M.B.E.** engineer-in-chief and inspector-general of ports and navigation, Basra; **Herbert J. Jones,** technical consultant, Hemingway and Co., Ltd.; **Captain John H. J. Martin,** works manager, Elswick and Scotswood Works, Vickers-Armstrongs, Ltd.; **Alan S. Milward,** deputy chief engineer, office of Crown Agents for Overseas Governments; **Peter Philip,** area manager, Dundee, North of Scotland, Hydro-Electric Board; **Donald H. Reed,** superintending examiner patent Office, Board of Trade; **Geoffrey H. G. Richards,** Director, Mechanical Transport Department, Sudan Government; **Harold Ringshaw,** chief engineer, R.F.A. Service; **Eric L. Ripley,** principal scientific officer, Structures Department, Ministry of Supply; **Vernon W. M. Roberts,** Electronics Department, British Thomson-Houston Co., Ltd., Rugby; **Jack Shackleton,** engineering superintendent of design, Atomic Energy Authority; **William J. Shea, M.B.E.,** principal, Ministry of Transport and Civil Aviation; **Robert Spence,** director and general manager, John Hastie and Co. Ltd. Greenock; **Donald Todd,** Deputy Director of Armament Supply, Admiralty; **George A. Vowles,** divisional controller, Yorkshire Division, British Electricity Authority; **Professor Frederick V. Warnock,** Head of the Department of Mechanical Engineering, Belfast Municipal College of Technology; **Norman H. A. Warren,** senior principal scientific officer, Admiralty Gunnery Establishment, Portland.

M.B.E. **Gilbert Anderson,** manager of welding and fabricating department, Bruce Peebles and Co., Ltd., Edinburgh; **Alfred J. Bolt,** senior experimental officer, Admiralty; **Antonin A. Brejcha,** senior technical officer, British Overseas Airways Corporation; **Jackson S. Chrisp,** chief maintenance engineer, Consett Iron Co., Ltd.; **Donald Dunsmore,** superintendent, Brush Electrical Engineering Co. Ltd., Loughborough; **George A. Edwards,** gauge design officer, Naval Ordnance Inspection Department, Admiralty; **Donald Fairweather,** chief of crystal production, Marconi's Wireless Telegraph Co., Ltd.; **Edwin J. Franklin,** works manager Remploy Factory, Longton, Staffordshire; **Walter Geary,** assistant superintendent, Metropolitan-Vickers Electrical Co., Ltd., Manchester; **Thomas W. Greaves,** safety officer, Dunlop Rubber Co., Ltd., Birmingham; **Frederick W. T. Hammett,** principal production inspector, Admiralty; **Arthur E. Hill,** manager, Glass Works, British Thomson-Houston Co., Ltd., Chesterfield; **George S. Jones,** chief engineer, Grosvenor Chater and Co., Ltd., Abbey Paper Mills, Holywell, Flintshire; **William A. Jones,** manager, Radford and Wollaton Unit, East Midlands Division, National Coal



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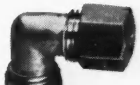

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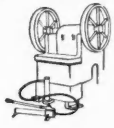
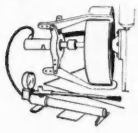
. . . still using muscle rather than machine for major operations in and about your works? If so, why not invest in the new 'Flexi-force' Power Kit which gives one man a pull (or push !) of up to 20 tons in any direction . . .

★ LIFTING



★ PULLING



★ PRESSING

★ PUSHING

. . . why make-do with out-dated methods and improvised hook-ups ? New 'Flexi-force' Hydraulic Power Kits will lift, pull, bend, clamp, spread and push infinitely better than ordinary levers, winches or crow-bars. Complete kits (with attachments suitable for your particular job) are now available on request.

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Board; **Cyril C. Knowles,** works manager, William McGeoch and Co., Ltd., Birmingham; **Charles J. Lever,** works manager, Siemens, Brothers and Co., Ltd., West Hartlepool; **Frank P. Macrae,** manager of structural shops, Sir William Arrol and Co., Ltd., Glasgow; **Frank Marriott,** works manager, Head Wrightson Steel Foundries, Ltd., Stockton-on-Tees; **Charles B. P. Morton, D.S.O., D.F.C.,** assistant to the chairman, Mathew Hall and Co., Ltd.; **Bertram S. Pears,** production manager, Imperial Typewriter Co., Ltd., Leicester; **Frederick S. Perry,** assistant manager, English Steel Corporation, Ltd., Sheffield; **Frederick J. Pewtner,** chief designer, E. N. V. Engineering Co., Ltd., Willesden; **Ernest E. Pheasey,** works manager, Foster, Yates and Thom, Ltd., Blackburn; **Edward W. Phillips,** managing director, Air Schools, Ltd., Derby; **Philip Phillips,** civil assistant, Royal Naval Air Repair Yard, Fleetlands, Hampshire; **William E. Phillips,** chief draughtsman, Harland and Wolff, Ltd., Bootle, Lancashire; **Melville J. Rattray,** city engineer, Georgetown Municipality, British Guiana; **Walter S. Read,** manager, Fraser and Chalmers Engineering Works, Erith; **William J. R. Richards,** deputy superintendent, Directorate-General of Works, Air Ministry; **Matthew Russell,** chief engineer, Cerebos group of companies, Middlewich Salt Co., Ltd., Cheshire; **Joseph F. Rust,** general manager and engineer, Newport Undertaking, Wales Gas Board; **John J. Sarche,** chief inspector, Ultra Electric, Ltd., Acton; **Herbert E. Toogood,** assistant engineering manager, Humber St. Andrews' Engineering Co., Ltd., Hull; **Henry E. Wasser,** chief testing engineer, Midlands Division, British Electricity Authority; **Arthur W. Whittaker,** senior executive engineer, Telecommunications, General Post Office; and **Frank Wood,** works manager, Turner Brothers Asbestos Co., Ltd., Hindley Green.

PERSONAL

Mr. T. Allen, general manager since 1948 of G.W.B. Furnaces Ltd., whose head office has been transferred to Dibdale Works, Dudley, Worcs., has been elected to the Board and has been appointed administrative director. **Mr. A. V. Francis** has been appointed chief engineer in charge of furnace design and sales.

Mr. E. H. Ball, a director of Associated Electrical Industries Ltd. and managing director of the British Thomson-Houston Co. Ltd., has been elected chairman of Birlec Ltd., Erdington, Birmingham 24. **Mr. W. W. Vinsen** and **Mr. E. S. Little** have been elected to the Board.

Mr. H. W. Barnett, manager of the Oxygen Division and London manager of The Butterley Co. Ltd. and of Hughes and Lancaster Ltd., has resigned after 18 years' service. He intends to utilise his 30 years practical and commercial engineering experience in his own advertising business by specialising in engineering accounts. His address is Room 15, Clarence House, Arthur Street, London, E.C.4.

Mr. R. T. Betts, M.B.E., B.Sc., A.C.G.I., A.M.I.C.E., general manager of McCalls Macalloy Ltd., Templeborough, Sheffield, has been elected a director of the company.

Mr. L. M. Broadway has been elected chairman of John B. Pillin Ltd., a member of the Wakefield Group of Companies, in succession to **Mr. Alonzo Limb,** who has resigned owing to ill health. **Mr. C. E. R. Millidge** and **Mr. J. J. Brookman** have been elected to the Board.

Mr. A. de M. Browne, B.Sc., A.R.C.Sc.I., managing director of the Hackbridge and Hewittic Electric Co. Ltd., Walton-on-Thames, Surrey, has been elected chairman of the company.

Mr. A. J. Brunker, B.Sc.(Eng.), A.C.G.I., D.I.C., A.M.I.E.E., has relinquished his position as general export manager and has been appointed chief engineer of E. K. Cole Ltd., Southend-on-Sea, Essex.

Mr. J. Collins, B.Sc.(Eng.), has been appointed generating-station superintendent at the Lots Road power station of the London Transport Executive. **Mr. W. Ward, M.Inst.F.,** has been appointed generating-station superintendent at the power station Greenwich, and **Mr. G. F. Withers, M.Inst.F.,** generating-station superintendent at Neasden.

Dr. Maurice Cook, joint managing director of the Metals Division of Imperial Chemical Industries Ltd., has been elected chairman of the British Non-Ferrous Metals Research Association, Euston Street, London, N.W.1, in succession to the **Hon. R. M. Preston,** who retired from office at the end of 1954.

Mr. David L. Davies, B.Sc.(Hons.) (Wales), G.I.E.E., has been appointed chief electronic engineer of Winston Electronics Ltd., Hampton Hill, Middlesex.

Mr. P. R. Dunn, B.Sc., M.I.E.E., has been appointed chief engineer of British Insulated Callender's Cables Ltd., in succession to **Mr. D. T. Hollingsworth,** who has recently been elected to the Board of the company.

Mr. Percy Evans, general sales manager of the Hopkinson Electric Co. Ltd., Cardiff, has been elected to the Board and has been appointed sales director of the company.

Mr. W. D. D. Fenton, secretary of the North of Scotland Hydro-Electric Board, relinquished his position to take up his new post as deputy chairman of the Uganda Electricity Board. **Mr. H. W. Simpson, M.A., LL.B.,** succeeded Mr. Fenton as secretary, and **Mr. J. C. N. Baillie,** development engineer of the North of Scotland Board, has been appointed chief commercial officer.

Mr. F. S. Follett has been promoted chief scientific officer and appointed principal director of Equipment Research and Development (Air), Ministry of Supply.

Mr. J. C. Gridley, C.B.E., chairman of the Vacuum Oil Co. Ltd., has been elected to the Board of Powell Duffryn Ltd.

Mr. M. M. Hallett has been appointed managing director of Chamberlin & Hill Ltd., Walsall, Staffs.

Mr. A. A. Hampson, chief planning engineer of the Standard Motor Co. Ltd., has been appointed a special director with the title of director of planning.

Lord Hives, C.H., M.B.E., LL.D., D.Sc., has relinquished his position of joint managing director of Rolls-Royce Ltd., Derby, but remains executive chairman of the company. **Mr. A. G. Elliott, C.B.E.,** has relinquished his position of joint managing director and chief engineer of the company and has been appointed executive vice-chairman. **Mr. J. D. Pearson, Wh.Sc., B.Sc.(Eng.),** a director of the company and chief executive officer of the aero division, has been appointed managing director of the aero-engine division. **Dr. F. Llewellyn Smith, M.Sc.,** a director of the company and chief executive officer of the motor-car division, has been appointed managing director of the motor-car division. **Mr. A. A. Rubbra, B.Sc.,** deputy chief engineer of the aero-engine division, has been elected to the Board as a technical director. **Mr. A. F. Kelley, B.Sc.,** general manager (manufacturing) of the aero-engine division, has been elected to the Board. **Mr. A. A. Lombard, F.R.Ae.S.,** has been appointed chief engineer of the aero-engine division. **Mr. D. R. McDonald, C.A.,** has been appointed secretary of the company.

Mr. L. Howles, C.B.E., M.I.E.E., M.I.Struct.E., F.R.S.A., chairman of the South-Western Electricity Board, has been elected chairman of the Industrial Development Committee, appointed by the Council of the British Electrical Development Association, with the object of fostering and developing the use of electricity in industry. **Mr. J. F. Smith, B.Sc., M.I.E.E.,** chief commercial officer of the South Wales Electricity Board, has been elected vice-chairman of the Committee.

Mr. T. E. Laing has been elected a director of British Resin Products Ltd., Devonshire House, Piccadilly, London, W.1.

Mr. J. F. Lockwood has been elected chairman of Electric & Musical Industries Ltd., Hayes, Middlesex, in succession to **Sir Alexander Aikman,** who has relinquished his position as chairman, but remains a member of the Board.

Mr. D. N. de Mattos, B.Sc., has been appointed sub-district manager of the district office of the British Thomson-Houston Co. Ltd., at 119 Victoria Street, Bristol 1.

Mr. J. A. J. Nicholas has been appointed sales director of the Regent Oil Co. Ltd., 117 Park Street, London, W.1, in succession to **Mr. G. E. G. Hope-Johnstone,** who resigned from the Board to take up his appointment as vice-president of Trinidad Leaseholds (Canada) Ltd. **Mr. G. W. Limmer** has been appointed commercial sales manager.

Mr. K. S. Peacock, chairman and managing director of Guest, Keen and Nettlefolds Ltd., has been elected a director of the United Steel Companies Ltd.

Mr. C. J. Pratt, A.M.I.Chem.E., A.M.I.P.E., A.I.I.A., has been appointed work study and productivity officer of the Association of British Chemical Manufacturers, 86 Strand, London, W.C.2.

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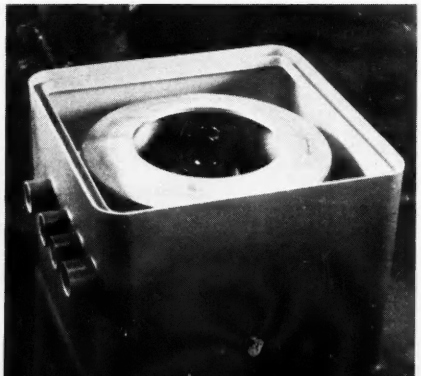

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Mr. E. W. S. Press has been promoted to be deputy chief scientific officer and has been appointed director of chemical inspection, Ministry of Supply, Kidbrooke.

Major-General H. E. Pyman, C.B., C.B.E., D.S.O., general officer commanding the 11th Armoured Division, B.A.O.R., has been appointed to be Director of Weapons and Development, War Office, London.

Mr. John S. Rolph, general manager of the Marine Department, and **Mr. R. F. Baldwin,** general manager of the Electrical Department, of W. B. Dick & Co. Ltd., 46 Grosvenor Street, London, W.1, have been elected to the Board.

Mr. R. T. Rolfe, O.B.E., F.R.I.C., F.I.M., has resigned from the position of chief metallurgist to W. H. Allen, Sons & Co. Ltd., Bedford, but will continue to serve in a consultative capacity. **Mr. J. R. Bryant, B.Sc.,** succeeds Mr. Rolfe as chief metallurgist and head of the laboratory.

Dr. R. J. Sarjant, O.B.E., D.Sc., F.I.M., has been appointed director of research, and Dr. A. H. Sully, M.Sc., F.Inst.P., F.I.M., associate director of research, of the British Steel Castings Research Association, Broomgrove Lodge, Sheffield 10.

Mr. S. T. Shipway, chief engineer and designer of Modern Machine Tools Ltd., Coventry, has been appointed technical director of the company.

Sir Ewart Smith, M.A., M.I.Mech.E., technical director of Imperial Chemical Industries Ltd., has succeeded **Mr. Tom Williamson, C.B.E., J.P.,** as chairman of the British Productivity Council, 21 Tothill Street, London, S.W.1.

Dr. C. J. Smithells, M.C., director of research of the British Aluminium Co. Ltd., has been awarded the Institute of Metals (Platinum) Medal for 1955. The Rosenlain Medal of the Institute has been awarded to **Dr. W. A. Baker,** and the W. H. A. Robertson Medal and Premium for 1954 to **Professor Hugh Ford** and **Mr. J. G. Wistreich.**

Mr. A. G. Stewart, chairman and general managing director of Stewarts and Lloyds Ltd., has been elected President of the British Iron and Steel Federation, Steel House, Tothill Street, London, S.W.1, in succession to **Mr. G. H. Latham,** chairman and managing director of the Whitehead Iron and Steel Co. Ltd. **Sir Ernest Lever,** chairman and chief executive officer of Richard Thomas & Baldwins Ltd., and The Steel Company of Wales Ltd., has been named as President-elect.

Mr. W. A. Turner, M.I.E.E., has been appointed Principal of the School of Electronics, established at Liverpool by the Automatic Telephone and Electric Co. Ltd.

Mr. E. H. Underwood, O.B.E., has been appointed director of public relations to the United Kingdom Atomic Energy Authority, Bedford Chambers, Covent Garden, London, W.C.2.

Mr. C. T. Wilkins, O.B.E., F.R.Ae.S., has been appointed chief designer, **Mr. J. P. Smith,** deputy chief designer, and **Mr. A. G. Peters, A.F.R.Ae.S.,** and **Mr. E. R. Owen,** assistant chief designers, of the de Havilland Aircraft Co. Ltd., Hatfield. **Mr. W. A. Tamblin, A.F.R.Ae.S., A.M.I.N.A.,** has been appointed chief designer and **Mr. F. Hamilton, A.F.R.Ae.S.,** assistant chief designer of the Christchurch establishment of de Havillands.

Mr. G. H. B. Wilson, managing director of Raleigh Industries Ltd., has succeeded **Sir Harold Bowden, Bt., G.B.E.,** as chairman of the company.

Sir James Reid Young, C.A., F.C.I.S., has relinquished his executive duties and retired from the Board of the subsidiary companies, but remains a director of Vickers Ltd. and Metropolitan-Cammell Carriage and Wagon Co. Ltd. **The Viscount Knollys, G.C.M.G., M.B.E., D.F.C.,** has been elected deputy chairman of Vickers Ltd. **Major-General C. A. L. Dunphie, C.B., C.B.E., D.S.O.,** has been elected chairman of Vickers-Armstrongs Ltd. and retains his present office of managing director. **Mr. E. J. Waddington, A.C.A.,** has been elected a director, and has been appointed director of administration of Vickers Ltd. and director of finance and administration of Vickers-Armstrongs Ltd. **Mr. E. P. Tomlinson, A.C.A.,** has been appointed secretary of Vickers Ltd.

BUSINESS NOTES

Ransome and Marles Bearing Co. Ltd., Newark-on-Trent, has concluded an agreement with North Eastern Trading Estates Ltd., for an extension to its factory at Annfield Plain, Co. Durham.

The David Brown Companies have acquired Tickford Ltd., Newport Pagnell, Bucks., motor car body builders. Mr. Ian Boswell will continue as managing director of Tickford Ltd.

Degenhardt & Co. Ltd. have opened a Carl Zeiss Agency for Great Britain at 32 Maddox Street, London, W.1.

Polford Engineering Co. Ltd., Heaton Junction, Newcastle-upon-Tyne 6, are now manufacturing the Polford range of foundry plant and equipment. Thos. W. Ward Ltd., Albion Works, Sheffield, are the sole selling agents. Mr. C. W. Coan, chairman, Mr. G. Pollock, M.I.B.F., Mr. S. K. Edwards and Mr. G. R. Chetwynd, M.P., are directors of the company.

Standage Power Couplings Ltd. have removed their works, owing to expansion of their business, from Blackstock Road, London, to a modern factory at Telscombe Cliffs, Newhaven, Sussex. Tel. No.: Peacehaven 2335.

The F. J. Stokes Machine Company, 5500 Tabor Road, Philadelphia, Pa., U.S.A., has established a new International Division for the control of their overseas activities. It will be directed by Mr. Charles W. Nicholson.

The Timber Fireproofing Co. Ltd., Market Bosworth, have further increased production and are extending their Oxylene Boram factory. Mr. H. Lundy, B.Sc., has joined the company and has taken charge of the technical service department.

Wild-Barfield Electric Furnaces Ltd., Watford-By-Pass, Herts., have acquired the induction heating business of Wickman Ltd. Manufacture of induction heating equipment will continue at Oxgate Lane, London, N.W.2, and continuity of service has been assured. Mr. F. L. Gladwin, who has been associated with the Wickman induction heating business since its inception, has been appointed sales manager of the Induction Heating Department of Wild-Barfield Electric Furnaces Ltd.

Blick Engineering Ltd., Bedesway, Bede Tarding Estate, Jarrow, Co. Durham, have acquired the high vacuum engineering business of " Blickvac " and have changed the name of the company to Blickvac Engineering Ltd. The Board consist of Mr. O. Moor, M.A.(Cantab.), F.Inst.D., chairman and joint managing director of Blick Time Recorders Ltd., Mr. R. A. Pearson, M.A.(Cantab.), F.Inst.D., joint managing director of Blick Time Recorders Ltd., Mr. J. Todd, A.M.I.E.E., and Mr. G. Wall, B.E.M.

EXAMINATION COURSES IN PLANT ENGINEERING

A scheme of examinations in Plant Engineering has been drawn up by the City & Guilds of London Institute's Advisory Committee. The scheme is intended to meet the needs of those engaged in the selection, installation, maintenance, or control of fixed or mobile plant throughout industry.

Examination courses, approved by the Council of Incorporated Plant Engineers as meeting the examination requirements for their Associate Membership, are designed to follow the successful completion of an Ordinary National Certificate course in mechanical or electrical engineering.

Details of the examination courses are given in a joint notice issued by the City and Guilds of London Institute and Incorporated Plant Engineers.

A Certificate in Plant Engineering will be awarded to successful candidates, and the possession of this Certificate will give exemption from the technical part of the entrance examination of Incorporated Plant Engineers. In addition, the City and Guilds of London Institute will award a Full Technological Certificate (countersigned by the President of Incoroporated Plant Engineers) to candidates who have gained the Plant Engineering Certificate and have an Ordinary National Certificate or higher qualification.

Full details of the scheme of examinations in Plant Engineering may be obtained from the Department of Technology of the City and Guilds of London Institute, 31 Brechin Place, South Kensington, London, S.W.7, the General Secretary of Incorporated Plant Engineers, Solihull, Birmingham, or through the Principals of technical colleges.

O.E.E.C. TO STUDY CURRENT ENERGY PROBLEMS

Monsieur Louis Armand, Director-General of the S.N.C.F. has agreed, with the approval of the French Government, to carry out an enquiry, on behalf of O.E.E C., on current energy problems in Europe. Concern is felt at O.E.E.C. about the possible effects of a continued rise in energy production costs on the evolution of the European economy, the financial stability of Member Countries and the living standards of their populations. The Organisation therefore wishes to study these problems in detail and to decide how they should be dealt with both on the national and on its own, intergovernmental level.

Monsieur Armand, who is well-known in many countries, especially as President of the International Railways Union, is an expert of international repute.

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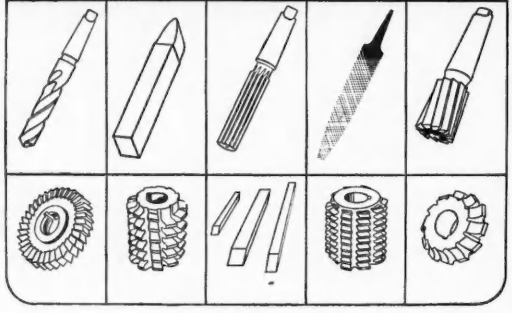

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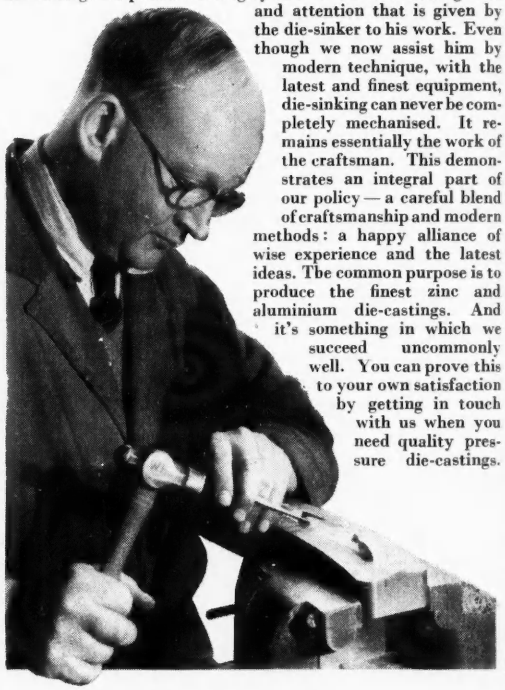

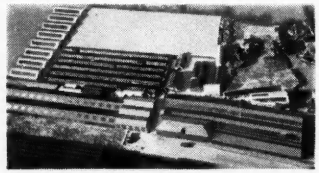

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EXHIBITIONS

Business Efficiency Exhibition. February 8th to 11th at Granby Hall, Leicester. Organisers: The Office Appliance and Business Equipment Trades Association, 11/13 Dowgate Hill London, E.C.4.

International Agricultural Machinery and Equipment Exhibition. February 13th to 20th at the Palais de Centenaire, Brussels. Organisers: Societe de Mecanique et d'Industries Agricoles A.A., 29 Rue de Spa, Brussels.

Hardware Trades Fair. February 14th to 18th at the Horticultural Hall, Vincent Square, London, S.W.1. Organisers: Universal Exhibitions Ltd., 74 Holland Park, London, W.11.

Leipzig International Fair. February 27th to March 9th and September 4th to 9th. Agents: Willoughby & Young, 6a Smith Street, London, S.W.3.

International Agricultural Machinery Exhibition. March 1st to 6th at Parc des Expositions, Porte de Versailles, Paris. Agent: Mr. R. C. Liebman, 178 Fleet Street, London, E.C.4.

Frankfurt International Trade Fair. March 6th to 10th. Agents: LEP Transport Ltd., Sunlight Wharf, Upper Thames Street, London, E.C.4.

Vienna International Spring Fair. March 13th to 20th. Agents: British-Austrian Chamber of Commerce, 29 Dorset Square, London, N.W.1.

A.S.T.E. Western Industrial Exposition. March 14th to 18th at Los Angeles, California. Organisers: American Society of Tool Engineers, Puritan Avenue, Detroit 38, Mich., U.S.A.

Electrical Engineers (A.S.E.E.) Exhibition. March 15th to 19th at Earls Court, London, S.W.5. Organised for the Association of Supervising Electrical Engineers, 23 Bloomsbury Square, London, W.C.1.

Utrecht International Spring Fair. March 22nd to 31st. Agent: Mr. W. Friedoff, 10 Gloucester Place, London, W.1.

Copenhagen International Fair (Technical Section). March 25th to April 3rd. Organisers: Dansk Udstillings Syndikat A/S, Forums Anneks Julius, Thomsens Plads, Copenhagen K, Denmark.

Factory Equipment Exhibition. March 28th to April 2nd at Earls Court, London. Information: Mr. J. E. Holdsworth, 117 Kingsway, London, W.C.2.

Milan International Trade Fair. April 12th to 27th. Agent: Dr. V. Schiazzano, 652 Grand Buildings, Trafalgar Square, London, W.C.2.

Lyons International Trade Fair. April 16th to 25th. Agents: Robert Brandon and Partners Ltd., 47 Albemarle Street, London, W.1.

Swiss Industries Fair. April 16th to 26th at Basel. Information: Swiss Legation, 18 Montague Place, London, W.1.

Liege International Trade Fair. April 23rd to May 8th. Organisers: Foire Internationale de Liege, 17 Boulevard d'Avroy, Liege, Belgium. Agents: Mattis Industries Ltd., 252 Abbey House, Victoria Street, London, S.W.1.

Physical Society's Exhibition of Scientific Instruments and Apparatus. April 25th to 28th at the Royal Horticulutral Hall, Vincent Square, London, S.W.1. Organisers: The Physical Society, 1 Lowther Gardens, London, S.W.7.

British Industries Fair. May 2nd to 13th at Olympia, London, and Castle Bromwich, Birmingham. Information: British Industries Fair Ltd., 9 Kingsway, London, W.C.2. or 95 New Street, Birmingham 2.

Dublin Spring Show and Industries Fair. May 3rd to 7th at Ballsbridge, Dublin. Organisers: Royal Dublin Society, Ballsbridge, Dublin.

Northern Radio Show. May 4th to 14th at the City Hall, Manchester. Organisers: The Radio Industry Council, 59 Russell Square, London, W.C.1.

Paris Trade Fair. May 14th to 30th. Agent: Mrs. M. Hyde-Joucla, 14 Rugby Chambers, Rugby Street, London, W.C.1.

Canadian International Trade Fair. May 30th to June 10th in Toronto. Information: Canadian Government Exhibition Commission, Canada House, Trafalgar Square, London, S.W.1.

Building Plant Exhibition. June 8th to 15th at Queenslie Industrial Estate, Glasgow. Organisers: Ministry of Works, Lambeth Bridge House, London, S.E.1.

International Water Supply Exhibition. July 18th to 21st at the Royal Horticultural Society's New Hall, Greycoat Street, London, S.W.1. Information: Mr. L. Millis, O.B.E., International Water Supply Association, 34 Park Street, London, W.1.

National Radio Show. August 24th to September 3rd at Earls Court, London. Organisers: The Radio Industry Council, 59 Russell Square, London, W.C.1.

Instrument Exhibition and Conference. September 12th to 16th at Shrine Exposition Hall, Los Angeles. Organisers: Instrument Society of America, 3443 South Hill Street, Los Angeles 7, California.

All-British Trade Fair. September 29th to October 16th in the Tivoli Gardens and the Forum, Copenhagen, Denmark. Organisers: British Overseas Fairs Ltd., 21 Tothill Street, London, S.W.1.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

APPOINTMENTS VACANT

ARMSTRONG SIDDELEY, Coventry, have vacancies on interesting important work in Stress Department on Strength Investigations and Calculations—Gas Turbines. Higher National, Engineering or Mathematics Degree minimum qualification, experience unnecessary. Same department invites similarly qualified applicants for work on engine installation in prototype/experimental aircraft. Reply Reference CG/DRE.1, Technical Personnel Officer, **Armstrong Siddeley Motors,** Coventry.

TECHNICIANS.—Several vacancies are available for technicians and men having design experience and holding 1st Class Honours Degree in Mechanical Engineering and having practical experience preferably in Marine Engineering or alternatively experience on the mechanical side for the generation of power for land purposes. They are required for work on the production of power from atomic energy, and will be employed initially at Harwell. Age 27-35. Good salaries will be paid to men holding the necessary qualifications.

DRAUGHTSMEN.—Several vacancies are available for draughtsmen holding Higher National Certificates, for work on the production of power from atomic energy. Work would be initially at Harwell. Age 30 or over. Good salaries will be paid to men having the necessary experience.

SENIOR PROJECT ENGINEER.—A vacancy is available for a Senior Project Engineer to head a group for the production of power from atomic energy. Applicants should have a background of experience, preferably in Marine Engineering, or alternatively experience on the mechanical side of the generation of power for land purposes. In addition, applicants should have scientific qualifications in the form of 1st Class Honours Degree in Marine or Mechanical Engineering and should for preference be in the range 35-40. Good salary will be paid to a man meeting the stated requirements. Employment will be at Harwell initially.

Apply to Box. No. 17, " The Engineers' Digest," 120 Wigmore Street, London, W.1.

PHYSICISTS.—A vacancy is available for a Physicist holding a Ph.D. Degree, and having practical experience, for work on the production of power from atomic energy, and to be employed initially at Harwell, age 30-35.

A vacancy is also available for an Assistant to the above, age 26-30.

Good salaries will be paid to men holding the necessary qualifications. Write Box No. 18.

MECHANICAL ENGINEER required for work on the design of small electro-mechanical equipments. Applicants should have served an engineering apprenticeship, or the equivalent, together with several years' experience in the field of design. Small model shop facilities available to Engineer. Greenford area. Pensionable and salary commensurate with ability. Apply giving age and fullest details of experience to Box 20.

WORK STUDY.—A young man, trained to introduce methods improvements is required to assist with the introduction of work study into a large and expanding radio manufacturing company. This is a new post and offers almost unlimited prospects in a field where such advanced techniques as printed circuits are just beginning to make their impact on production methods. Applicants should have had at least two years experience of this work and should also have had a good technical or general education. Commencing salary £500 to £700 according to experience. Write stating age and details of career, including education. Box No. 21.

ENGINEER.—An experienced mechanical engineer is required for work in connection with the development of equipment for automatic production processes. Applicants must be capable of undertaking all the practical mechanical work involved in the making of prototype machines. Apply to the Personnel Manager, **Pye Limited,** St. Andrews Road, Cambridge.

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BOOKS RECEIVED

The Design of Cylindrical Shell Roofs. By J. E. Gibson, M.Sc.(Maths.), Ph.D., A.M.I.C.E., and D. W. Cooper, B.Sc., A.M.I.Struct.E. 200 pp., 76 illustrations. Publishers: E. & F. N. Spon Limited, 22 Henrietta Street, London, W.C.2. Price: 35/-.

The shell roof is a form of engineering construction which has become popular in Great Britain during the past decade, though it was first used on the Continent about thirty years ago. To-day, the shell concrete roof ranks as an important constructional technique. For a long time its development was held up because of the complexity of the calculations involved, but it is now becoming a recognised method of building; empirical data are available, together with a number of mathematical tools, for solving the problems involved.

Both of these aspects are thoroughly dealt with in this book. The necessary mathematics are fully set out, and there is an important section on the use of matrices. At the same time, such practical questions as reinforcement are given detailed consideration. After a general treatment of the theory of cylindrical shells, the authors follow through the complete problems raised by specific types, with and without edge beams. The result is a book which is of great value to architects and engineers and also of direct interest to teachers and students who wish to keep abreast of a development which is rapidly becoming too important to be neglected.

Plastics Engineering Handbook. 2nd Edition, 1954. 849 pp., 414 illustrations. Publishers: Reinhold Publishing Corporation, New York, and Chapman & Hall Limited, 37 Essex Street, London, W.C.2. Price: 120/-.

So much information has been made available since the publication in 1947 of the original Handbook of the Society of the Plastics Industry, Inc., that it has been found necessary to expand this new edition to nearly twice the size of its predecessor. Thus, complete chapters of all new material have been added, such as that on Tooling with Plastics, which describes the newly developed uses of plastics in production tools for the aircraft, automotive, and other industries.

Another important innovation is the special fold-out adhesives chart in the chapter on Cementing and Assembly. This chart, compiled from questionnaire forms returned from producers of adhesives throughout the U.S.A., is probably the most complete tabulation available anywhere on the types and characteristics of adhesives used to join plastics to each other or to other materials.

This valuable publication, undoubtedly one of the most comprehensive compilations of engineering knowledge on the design, materials, and processing of plastics products, will provide suppliers, designers, manufacturers, finishers, and users of plastics with a wealth of practical and vital information in a readily usable and easily assimilable form.

Engineering Metallurgy. By E. M. H. Lips, Dr.Ing.(Aachen). 265 pp., 170 illustrations. Published by Philips' Technical Library, Eindhoven, Holland, and distributed in the U.K. and Eire by Cleaver Hume Press Ltd., 31 Wright's Lane, Kensington, London, W.8. Price: 32/6.

Knowledge of the properties of the newest materials, in addition to data on classical materials, is absolutely indispensable in mechanical engineering design, where the fullest use must be made of the various qualities of a material, not only for economy but also for meeting technical requirements.

In this book, the subject of metallurgy is treated essentially with regard to its usefulness to the practical engineer, and contains a wealth of technical information, concisely set out, both on the characteristics of the materials concerned and on their heat treatment.

In his function as a metallurgist, the author is in daily touch with a great range of design problems in many branches of engineering. This book cannot, therefore, fail to be of value to all those whose work entails engineering design or the application of metals. Certainly, it will greatly assist those concerned in practical processes to understand their basic nature and will help them to appreciate the important changes which occur during manufacture. In Great Britain it should be of special value in the Higher National Certificate Courses in Production Engineering.

Valves for A.F. Amplifiers. By E. Rodenhuis. 155 pp., 97 illustrations. Published by Philips' Technical Library, Eindhoven, Holland, and distributed in the U.K. and Eire by Cleaver Hume Press Ltd., 31 Wright's Lane, Kensington, London, W.8. Price: 10/6.

Although all kinds of satisfactory amplifiers are available on the market, many radio amateurs prefer to build their own. This book shows the radio designer and amateur how this can be done. The author wisely keeps theoretical details to a minimum and provides a mass of useful information and practical hints, with the object of getting the reader to use his own ingenuity, rather than to employ the popular procedure of constructing equipment from ready-made blueprints.

The book centres mainly on the fullest possible data relating to a number of valve types specially designed for use in sound amplifiers, and much thought has been devoted to the specification of components, their layout on the chassis, the method of assembly, tone controls, and mixing circuits. An important section of the book deals with the design of eight complete amplifiers, and comprises a series of designs for outputs ranging from 3 to 100 W.

With its numerous tables of valves and components, this handy little volume should also prove useful for reference purposes.

LATEST INDUSTRIAL LITERATURE

1. Industrial Scaffolding. Descriptive details and illustrations are given in a 6-page pamphlet of a rapid, easily erected system of industrial sectional scaffolding, adaptable to a wide range of building and other operations. A feature of the system is that no tools are required and there are no nuts, bolts, or screws employed. Furthermore, no training is required and, provided that the very simple erection instructions are carried out, supervision is unnecessary.

Only two basic units are used, i.e., a frame 4 ft in width and a link bar. By means of these, for instance, a 20-ft tower can be erected in less than 20 minutes. Vertical members of the frame and link bar are manufactured from standard-size scaffolding tube, so that any standard scaffolding fitting can be used in conjunction with the sectional scaffolding, the units of which can be stacked easily when not in use.

2. Solder Products. A comprehensive range of solder products, including cored solder, lamp solder, solid solder wire, solid solders, solder paints, and soldering fluxes, is described in an illustrated 8-page catalogue.

A supplementary leaflet describes a high-speed soldering iron with many interesting features. For instance, the iron heats up from cold in only 6 seconds and, when not in use, is automatically switched off; furthermore, it can be used with voltages from 2·5 to 6·3, it is more powerful than conventional 150-W irons, and it is equally suitable for light wiring work or for heavy soldering on chassis.

3. Electrical Control Gear. Comprehensive details are given in a beautifully produced and illustrated 16-page booklet of a wide range of electrical control gear, including contactor gear, control panels, isolators, press-button units, overloads, and drum controllers.

Produced by a firm with nearly 25 years of experience in the field of industrial electric heating equipment and of control gear for resistance, induction, and arc furnaces, this equipment is eminently suitable for numerous applications in a range from 10 to 1400 A and voltages up to 550 V a.c. or 600 V d.c.

4. Glue Pen. A leaflet describes and illustrates an ingenious fountain-pen type of adhesive dispenser for paper, etc. Pressure on the tip of the pen releases a small dot of adhesive from an easily replaceable cartridge in the barrel, each cartridge containing sufficient for about 5000 "dots." As a result, adhesive is applied economically, rapidly, and efficiently. Furthermore, when not in use, the adhesive is sealed in the pen, without any risk of leakage or evaporation.

The adhesive itself is of the plastic type and dries almost instantaneously. Nevertheless, it is clean and extremely strong, and, if desired, can be removed without smudging or damaging the surface to which it is applied.

5. Precision Feeler Gauges. A leaflet describes and illustrates a range of precision feeler gauges with a patent dispenser, with many advantages, among which may be mentioned:—The feeler blades are freely removable from the holder, when the clamp, which can also be used as a pocket clip, is pressed down; the blades can easily be fanned out for selection, without any risk of damage to the thinner gauges; blades can be made to project only the desired extent, thereby avoiding unnecessary bends; both ends of the blade can be used, one end being of the parallel type, and the other tapered; any desired combination can readily be obtained; and cleaning is easily effected without screwing.

6. Flexible Couplings. A range of elliptical rubber buffer flexible couplings is described and illustrated in a 4-page brochure. These couplings are claimed to be superior to other rubber or leather types, owing to the greater number of buffers under compression fitting into the same size of coupling. Other advantages include the fact that the two shafts are free to move axially, and the coupling permits a fair amount of misalignment; furthermore, the shape and flexibility of the rubber buffers ensure that even pressure is exerted by each driving lug.

These couplings, which are suitable for either direction of rotation, are made in two different types, i.e., with solid halves, principally used in conjunction with electric motors, which can be moved away axially without difficulty; and split-type couplings, which enable an intermediate shaft to be removed without disturbing its neighbours.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● ***ULTRA-HIGH-FREQUENCY HEATING***

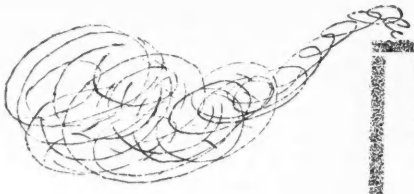
It is claimed that the application of ultra-high-frequency heating for fusing ceramic or vitrifiable colour upon glassware, china, and pottery will reduce processing time to some three minutes, as compared with the $2\frac{1}{2}$ to 4 hours hitherto required. Another useful application would be the baking or curing of plastic coatings applied to copper wire, etc. It is proposed that the process should be carried out in an apparatus comprising a cavity resonator operated at a frequency in excess of 1000 megacycles, means of control being provided for adjusting the amount of high-frequency energy supplied to the resonator. The electrical energy would be supplied by a magnetron or a klystron. The use of ultra-high frequency in the range from 1000 to 3000 megacycles is recommended, as at such high frequencies the article, if of dielectric nature, is heated by molecular hysteresis because the polarity of the molecules is constantly reversed. The force necessary to reverse the polarity of the molecules is a function of the applied potential and, when this potential is held constant, the rate at which temperature of the piece rises becomes a function of the applied frequency. Where a coating is to be fused, the object to which the coating is applied forms part of the material being heated. It is claimed that, as the polarity of the molecules of the entire object reverses instantaneously when the correct potential and frequency are applied, there will be no strain set up in the article, and no time will be required for penetration of heat by conduction from the outside towards the centre of the article, so that the latter can be brought up to the desired temperature with very great rapidity.

● ***PRESSED AND SINTERED GLASS-POWDER SHAPES***

A recent development in the technology of glass fabrication closely resembles powder-metallurgical practice. This is a cold glass-working technique which enables glass to be formed into a wide variety of precise shapes and intricate patterns which would be impractical with conventional molten glass-forming technique. In the new process powdered glass is mixed with a binder, moulded, and sintered to form a vacuum-tight monolithic structure with a density of about 98% of that of the solid product. It is reported that the parts produced in this way retain the desirable characteristics of molten glass, such as thermal endurance, corrosion resistance, and dielectric strength. The product, however, is opaque; if desired, colourant matter may be introduced into the powder. The mechanical strength of the product is slightly less than that of a part made of solid glass. One characteristic of sintered glass, not found in glass worked by other methods, is its lack of continuous bubbles, which in drawn tubing and rods take the form of elongated seeds or hair lines. In the design of parts to be manufactured by this process, the requirements of straight press-type dry moulding must be adhered to. Irregular surfaces should be perpendicular to the press stroke and the axes of holes should be parallel with it. Undercuts and re-entrants should be avoided, and generous radii should be allowed between heavy and light sections. Where large pieces, irregular shapes, or small quantities are required, a slip-cast method analogous with ceramic technique can be used. The dry-pressing method allows a wide variety of shapes to be produced. Typical shapes are beads, cylinders, and headers, with outside diameters ranging from 0·06 to 2·0 in., and a minimum diameter of 0·03 in. In a semi-fired state both slip-cast and dry-pressed parts may be machined by conventional metal-working tools; after machining sintering is then completed.

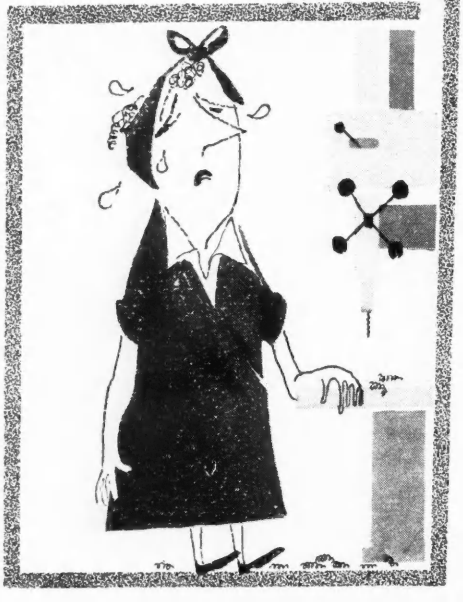
● ***HEAT-RESISTANT ADHESIVES***

It is reported that two heat-resistant adhesives have been developed for structural applications at temperatures as high as 600° F. One of these is suitable for metal-to-metal adhesive bonding, while the other is a modification developed for the fabrication of heat-resistant sandwich constructions. Because of their inherent heat-resistant properties, phenolic resins with alkaline catalysts were selected as the basic materials in the development of these adhesives. Application involves air drying, so as to evaporate practically all solvents; this is followed by pre-curing at 180° F, which has been found vital for the attainment of bond strength at elevated temperatures. Final curing is then carried out at 275° F under pressure. The extent to which pre-curing increases elevated temperature strength is illustrated by the fact that pre-curing results in a three-fold increase in the tensile-shear strength of bonds between aluminium specimens at 500° F. For



Meet Ethel Mary Sprott

It's mid-winter and she's sniffing because she's cold. She's fumbling because her fingers are frozen, she's fed up with the factory because it's like an ice-well. No heaters? Plenty! Trouble is, the building leaks heat like a sieve—especially through the roof! What's the answer? *



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Meet Ethel Mary Sprott

It's mid-summer and she's sweating and swearing because she's hot. She's getting careless because she's drowsy. She's fed up because the factory's like an oven. What's the trouble? No windows or fans? Not on your life! Feel that roof. It's *baking* hot. No wonder production is slacking off. So what? So . . *

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aluminium alloys the most suitable surface preparation is degreasing, followed by a ten-minute immersion in warm sulphuric acid-sodium dichromate solution at 150 to 170° F. Stainless steels are prepared by dipping for a few minutes in a dilute hydrofluoric-nitric acid bath. Obviously, only heat-resistant plastic materials require adhesives for elevated temperature operation. Outstanding among these are glass-reinforced plastics. The adhesive developed for sandwich construction has been successfully employed in the skin-to-core bonding of all-metal (aluminium) and all-plastic (glass-reinforced) sandwich constructions and in the splicing of honeycomb cores. The cores failed at a shear stress of about 200 psi at 500° F, while aluminium sandwich specimens, at 500° F have developed ultimate stresses in excess of 350 psi.

● ***CARBON REMOVAL FROM AUTOMOBILE ENGINE CYLINDERS***

A recent technical paper describes the development of a safe, economical, and easy method of removing combustion-chamber deposits. The new treatment uses a special fuel which removes the deposits as it burns. The method seems to show 70 to 80% recovery of power loss due to combustion-chamber deposits. There is also an indication that the removal of the deposit lowers the octane requirement of the engine. The fuel line is blanked off between the fuel pump and the carburetter, and the special fluid is fed by gravity directly to the carburetter float bowl, with the engine idling. The throttle is rapidly depressed and held for about one second, while the engine accelerates up to 3000 rpm. It is then released and the engine returns to idle speed. This is repeated until the fluid is consumed, an operation taking about ten minutes. For best results the throttle must be opened wide each time and not held down too long. Standard treatment is about 30 openings. Since the process is designed for normal conditions, it will be less effective at altitudes above 4000 feet and at temperaturs lower than 40° F. The process is claimed to be considerably less expensive than the current practice of removing the cylinder head and scraping deposits, and is less harmful to the engine than using strong solvents or oxygen burn-out methods. This new process removes combustion-chamber deposits by a combination of heat, pressure, and abrasive action. The fuel is ignited by the spark, as normally, but a substantial portion of it ignites spontaneously. Peak temperatures in the chamber are higher than with normal fuel, promoting deposit removal. The rapid release of energy accompanying auto-ignition creates high-velocity pressure vaves which knock the deposits loose from the cylinder walls. These deposits are buffeted about within the chamber and " sand-blast " remaining deposits before being blown out from the exhaust.

● ***FLOW CONTROL OF MAGNETIC MATERIAL***

In weighing and packaging nails, rivets, screws, washers, etc. by automatic apportioning devices, means must be provided to interrupt flow whenever the weighing device has received the specified weight of material. Instead of providing mechanical means for this purpose, a recent invention envisages " magnetic freezing " of the stream of material being conveyed toward the weighing device at the appropriate moment. This type of weighing device will be equipped with a switching mechanism which causes an electromagnetic system to be energised when the weighing device has received a predetermined quantity of material. The electromagnet will be so arranged that its field will attract the material on its way to the weighing device and thus stop its flow. If feeding of the material is effected by a conveyor, provision can also be made to bring its movement to rest automatically when the predetermined quantity of material has been delivered. A particularly interesting feature would appear to be the possibility of arresting the fall of metal while in mid-air and about to fall onto the weighing device after the specified full weight has been reached. Evidently, such a possibility should materially assist the attainment of high weighing accuracy, as it permits setting of the cut-off mechanism to a much higher degree of accuracy than hitherto attainable. In fact, this feature should prove especially useful in cases where quantities of iron powder have to be weighed or apportioned in measured quantities, as, for instance, in powder-metallurgy processes.

● ***SILICON NITRIDE BONDING FOR SILICON CARBIDE***

By using silicon nitride bonding, a silicon carbide material has been produced which is claimed to possess significant advantages over the usual bonded type. Its advantages are summarised as greater shock resistance, greater load-carrying capacity at high temperatures, and somewhat better thermal conductivity. The density of the new material is approximately that of fused alumina and slightly higher than that of fireclay. Its thermal conductivity is ten times that of fireclay and somewhat higher than that of the ordinary grade of silicon carbide. The specific heat equals that of the ordinary material, while its coefficient of thermal expansion is 12·5% higher. The superior properties of this material are especially marked in the higher-temperature range; thus, at 2450° F it exhibits a modulus of rupture of 5600 psi, as compared with 2000 psi for the ordinary material and 200 psi for fused alumina. The corrosion resistance of silicon carbide bonded with silicon nitride is stated to be somewhat better than that of the standard grade. In particular, it is resistant to acids and acid salts, and it can be used at room and

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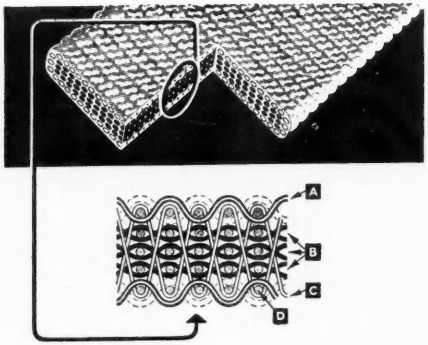

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elevated temperatures for the handling of mixed chlorides and the sulphates of iron, zinc, and tin which contain free acids. The abrasion resistance of the new product is also claimed to be excellent; its thermal shock resistance is said to be three times higher than that of the conventional product. The material is neither attacked nor wetted by molten aluminium and can be produced in sections considerably thinner than is possible with other refractories, while parts can be held to tolerances of ±0·005 in., with surfaces as smooth as those obtained on many metal castings. Several applications are under development, including acid-spray nozzles, microwave absorbents, pump impellers for corrosive materials, and pumping molten aluminium.

● *NOVEL HIGH-SPEED TURNING OPERATION*

A promising new method for the high-speed turning of shafting and metal stock with a high length-to-diameter ratio in general is proposed in a recent patent. The invention consists in carrying out a turning operation in which the workpiece is traversed by two cutting tools which are moved in unison towards and past one another along the workpiece and increasing the depth of cut of the two tools in unison as their cuts in the workpiece merge. This operation could be carried out with a lathe having two tool-holders which are traversed in unison from one end of the stock to the other, the holders starting from the opposite ends of the stock. The adjustment of the setting of the tools as they pass one another can be effected by any suitable trip mechanism, preferably by hydraulic control. The inventors also envisage application of their machining method to a profiling operation, in which one tool would operate to make a finishing cut to the generating cut made by the other. A lathe suitable for carrying out the turning operation will comprise a bed with the usual headstock and tailstock, and on the bed will be two saddles, slidable past one another on the bed, one leadscrew being provided for each saddle. Obviously, the cutting pressures, acting lengthwise on the workpiece and set up by the two tools, will act in opposition and tendencies to set up chatter or to bend the work will be cancelled out.

● *CORRECTING THE SHAPE OF CAST BLADES BY PRESSING*

When using the lost-wax process of precision casting it frequently happens that the resulting castings are not true to the shape intended but are to some extent distorted because of cooling stresses. Usually, the effect of the distortion is that the casting must be reshaped in order to conform to specifications. A recent patent describes how this shortcoming is overcome in the manufacture of cast turbine and compressor blades. The process consists in heating the blade casting to a temperature of, say, 650° C and then pressing the blade face, which is to be shaped accurately, against a die surface of correct shape. For this purpose, the press tool is set up on a press capable of delivering a pressure of about 50 tsi. The heated compressor blade is placed in the press tool, with its concave face resting on the convex surface of the bottom die. A pad of asbestos, preferably covered by graphite and white spirit as a lubricant, is then placed over the blade, and the press is operated to deliver pressure through the top die and the asbestos pad onto the blade. Owing to the pressure applied, the asbestos suffers plastic deformation and distributes the pressure evenly over the whole surface of the blade in contact with the top die, with the result that the lower face of the blade assumes the shape of the bottom die. All errors in shape will thus be transferred to the top surface of the blade, from which they must then be removed by polishing or grinding, if both surfaces are required to have correct shape. Since it is more difficult to correct the concave side of a compressor blade by polishing or grinding, it is the concave form which is corrected by the process and the convex side is then corrected by polishing. In the manufacture of turbine blading, however, the convex side is the more important and it is this side which is corrected by pressing, whilst the concave side is corrected by polishing or grinding.

● *HIGH-SPEED MILLING METHOD*

A recent patent describes a new high-speed milling method which is claimed to make possible the attainment of cutting rates far in excess of those of present-day practice, without sacrificing adequate tool life. The method has been conceived in recognition of the fact that one of the major causes responsible for shortening the life of tools and imposing a limit upon cutting speed is the vibration which exists in all types of cutters of conventional design. It is claimed by the inventors that this difficulty is overcome by providing the milling cutter with a greatly increased number of carbide teeth, set at a much smaller pitch than was hitherto believed practicable. Such a small pitch ensures that at least two of the teeth are in contact with the work at all times, thus reducing tool chatter; furthermore, by reason of the short time during which the individual teeth of the rapidly rotating cutter are in contact with the work, generation of heat is minimised. While previous tooth travel rates of carbide cutters in milling operations were never in excess of 1000 surface feet per minute, tooth travel rates of at least 2500 sfm and possibly 10,000 to 20,000 sfm are claimed for the new method. In order to maintain continuous effective chip loading of the teeth, feed rates of at least 600 ipm are required. No limitations are placed upon the depth of cut. The sole restriction is said to lie

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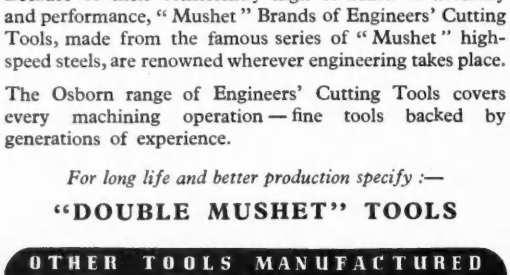

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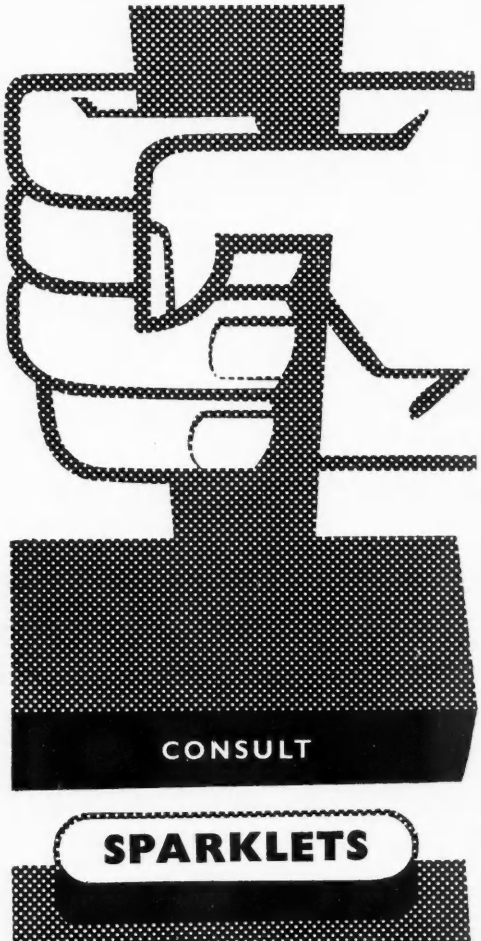

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in the relatively low horsepowers available in modern milling-machine spindles. If 100 hp were available, a depth of cut of approximately 0·18 in. could be attained, which, with one inch width of cut and a feed rate of 600 ipm, would result in the removal of 108 cu in. of steel per minute. Clearly, new types of milling machines would be required for this purpose.

● *NEW TYPE OF CONDUCTIVITY CELL*

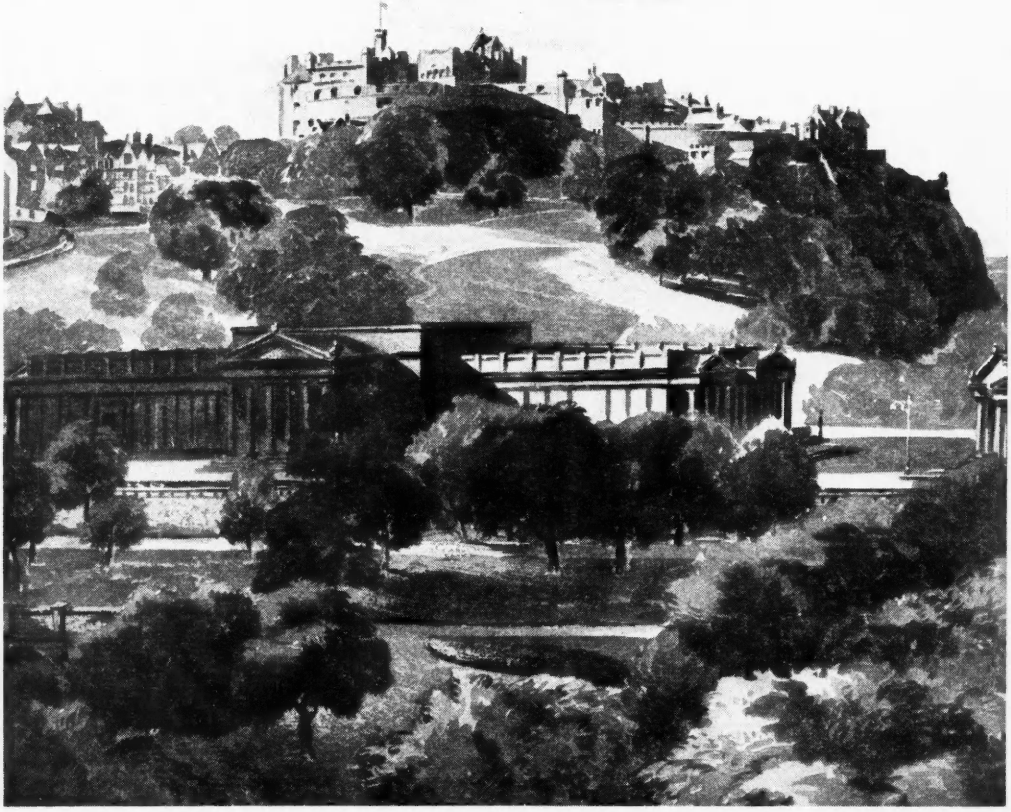
The development is reported of a new co-axial disc-type cell and valve assembly for detecting the salt content and other impurities in liquids. The new cell, which has certain advantages over existing devices of this kind, is to be used with salinity indicators and other conductivity devices for measuring impurities in excess of any desired preset value and for giving a warning signal, so that preventive steps can be taken against corrosion attack or contamination. The cell is claimed to possess many advantages not previously available for atomic-energy processes, and industrial, marine, chemical, petroleum, and other applications. The cell operates on the well known and generally used principle that salinity and other impurities in the liquid are detected by changes in the flow of current between the electrodes in the cell, the current varying with the conductivity of the solution examined. It is stated that the design of the new cell provides a uniform and unrestricted conduction path, with small random losses and consequently greater accuracy of measurement. A device for automatically compensating the temperature variation of the liquid can be included in the body of the cell where automatic temperature compensation is desired. In addition, the new cell can be easily and quickly cleaned. A special insulating material with zero water absorption is used to insulate the electrodes. A number of advantages is claimed for the new type of valve, through which the cell is inserted co-axially into the liquid. There is no possibility of liquid escaping to scald or burn the operator when the cell is inserted or removed from the liquid, because the valve cannot be opened unless the cell is fully seated, and the cell cannot be removed when the valve is open. Moreover, it is impossible to damage the cell during insertion or removal.

● *ELECTROSTATIC PAINT SPRAYING*

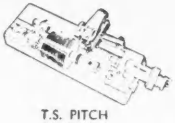
In a new paint-spraying process the paint is atomised by compressed air or by centrifugal force and then transferred to the workpiece by the action of a powerful electrostatic field. It is claimed that this electrostatic spraying process almost completely avoids the wastage of paint and produces a uniform coating; also, the process can be made fully automatic, where mass production is concerned. The equipment consists of a pump which delivers the paint from the storage container into a spraying tray, whence any surplus paint returns to the container *via* an overflow. One pole of a low-power d.c. source, with a potential of approximately 100 kV, is connected to the tray, the other pole being earthed. The component part to be painted and a conveyor which carries it past the spraying edge of the tray are also connected to earth. In this manner, an electric field is established between the spraying edge and the part to be painted, and the highest field gradients occur in the vicinity of the edge of the tray. Under the influence of the electric field, atomised paint is removed from the tray and carried towards the part to be painted along the electrostatic lines of force. Even those parts facing away from the tray are reached by the paint spray. The current consumption is very small and does not exceed a few milliamperes. The atomised spray is charged to the same polarity as the tray and it is possible, by means of electrodes which can either be insulated or connected to the spraying tray, to divert and shape the flow of the atomised paint.

● *DETERMINATION OF TRANSFORMATION TEMPERATURES IN STEEL*

An interesting method for determining the temperature at which the transformation from austenite to martensite begins to take place in steel (M_s-point) has been investigated, and it is reported that the method appears to be as reliable as the metallographic method and, at the same time, much more rapid. The method is based on the utilisation of the Curie point, at which temperature a cooling material recovers its magnetic properties, and a cooling curve is plotted corresponding to the increasing magnetic permeability of the steel being quenched. The equipment used for the test is simply an electrical transformer in which the specimen acts as a core. The specimen is heated to the critical point, then rapidly inserted in the apparatus, which consists of a glass oil-quench tank, a pick-up coil connected to a recording potentiometer, and an apparatus connecting a thermocouple from the specimen to a temperature recorder. When transformation from austenite begins, the specimen begins to become magnetic and this magnetism induces in the secondary coil an electromotive force which is recorded on the potentiometer. Thus, a curve representing temperature against magnetic permeability can be plotted. Like the metallographic method, the magnetic method is sensitive to inhomogeneities in the steel. A slight amount of banding or carbon segregation would definitely result in a high recorded M_s-temperature. The investigators also believe that there is a relationship between percentage of magnetic permeability and percentage of martensitic transformation, but further work will be required to verify this relationship.



Edinburgh Castle, Scotland. *One of a series featuring countries of the Commonwealth where 'Matrix' plants are established.*



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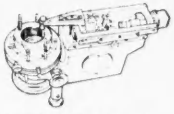
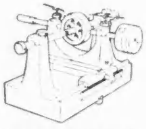
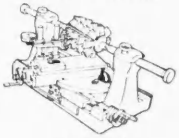
MACHINE TOOLS · PRECISION INSTRUMENTS & GAUGES
PRECISION TOOLS OF ALL TYPES



INTERNAL DIAMETER MEASURING MACHINE



FLOATING CARRIAGE MEASURING MACHINE



HOB FLANK ANGLE MACHINE

COVENTRY GAUGE AND TOOL CO LTD COVENTRY GT BRITAIN

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